

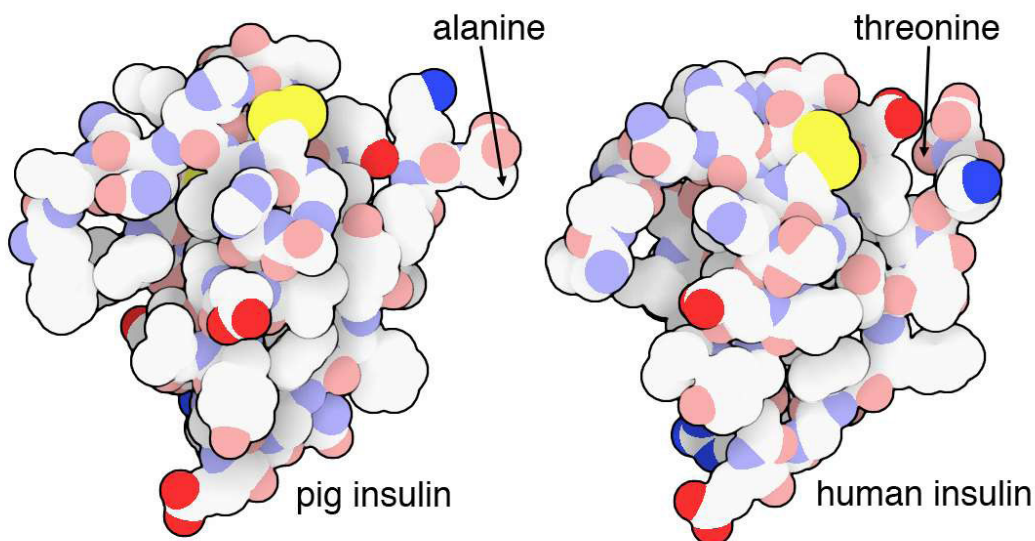
BULLETIN FOR THE HISTORY OF CHEMISTRY

Division of the History of Chemistry of the American Chemical Society



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Did she contribute to insulin production?

BULLETIN FOR THE HISTORY OF CHEMISTRY

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ANCIENT ANALOGUES OF CHEMICAL EQUATIONS

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Abstract

The symbolizing of chemical reactions with chemical equations goes back to Lavoisier and Berzelius. In Plato's *Timaeus*, his only dialogue devoted to science which was for many centuries the most influential of his works, we find analogues of chemical reactions which, when written as quantitative constitutive chemical equations, show very clearly that reactants and products are the analogues of molecules. Heisenberg and Bertrand Russell wrote about Plato's reactions, but they interpreted the reactants and products as atoms, and they did not write them as chemical equations. The writing of Plato's reactions in the form of chemical equations shows the power of this modern symbolism even when applied to Plato's analogues of chemical reactions, immediately allowing the modern chemist to see an analogue of the concept of molecule in Plato's geometrical atomism. His theory becomes then the first mathematical theory of the structure of matter at the three levels molecular, atomic and, as will be shown in the text, even sub-atomic, an unbelievable feat 2200 years before John Dalton and Amedeo Avogadro. His theory is also here compared with the atomic theory of Leucippus and Democritus.

The Birth of Chemical Equations

The modern way of symbolizing a chemical reaction with a chemical equation begins with Lavoisier and Berzelius. In William H. Brock's book *The Norton His-*

tory of Chemistry (1) we read that in one of his essays Lavoisier wrote:

In order to show at a glance the results of what happens in the solution of metals, I have constituted formulae of a kind that could at first be taken for algebraic formulae, but which do not have the same object and which do not derive from the same principles.

Brock comments:

The important point here was that Lavoisier used symbols to denote both constitution and quantity. Although he did not use an equals sign, he had effectively hit upon the idea of a chemical equation. ... once Berzelius' symbols became firmly established in the 1830s, chemists began almost immediately to use equations to represent chemical reactions.

We are today accustomed to the happy marriage between algebra and chemistry that allows us to represent chemical reactions with chemical equations.

Plato's Geometrical Atomism and His Reactions

The Greek philosopher Empedocles (ca. 440 BCE) of Akragas, today Agrigento in Sicily, as Bertrand Russell writes in his *History of Western Philosophy* (2)

established earth, air, fire and water as the four elements...Each of these was everlasting, but they could be mixed in different proportions and thus

produce the changing complex substances that we find in the world.

In Plato's *Timaeus* (3), his only dialogue devoted to science, Plato associated the shapes of four of the five platonic solids to the four elements of Empedocles: tetrahedron for fire, octahedron for air, icosahedron for water and cube for earth. Benfey and Fikes briefly discuss the reason for this choice (4). In *Timaeus* (Ref. 3, 55d, 55e and 56a, on pp 51 and 52), Plato writes:

We should allocate the figures...to fire, earth, water and air. Let's begin by assigning the cube to earth, because, of the four bodies, earth is the most inert—the hardest to move...we assign the most inert of the remaining figures to water, the most mobile to fire, and the figure that is intermediate in terms of mobility to air; the smallest to fire, the largest to water, and the one in between to air; and the most angular to fire, the second most angular to air and the least angular to water. Of them all, then, the one with the fewest faces is bound to be the most mobile, since it is altogether the sharpest and the most angular of the three figures; and is also to be the lightest, since it consists of the smallest number of identical parts.

Note that Plato had obviously the concept of weight but didn't have that of mass.

Why did he choose the regular polyhedra to represent the four elements? His was an esthetic criterion. We read (Ref. 3, 53a, p 47) that the four substances are "each of outstanding beauty." We also read (54e, p 47) that "there's an infinite number of right-angled scalene triangles" and that the scalene elementary triangle of Figure 1, two of which combine to form an equilateral triangle, is "the most beautiful of this infinite plurality of scalene triangles." Plato then writes four reactions between fire, air and water in which these elements can transform into each other (Ref. 3, 56d and e, p 51), which I write here in Plato's words just adding a numbering in square brackets:

[1] When water is broken up in its parts...the result might be one bit of fire and two bits of air; and [2] the fragments of air produced by the disintegration of a single bit of air could become two bits of fire. Conversely...[3] two bits of fire combine to make one air-figure. And [4] two-and-a-half bits of air join together into a simple complete water-figure.

Schematically the four reactions are the following:

[1] Water = Fire + 2 Air

[2] Air = 2 Fire

[3] 2 Fire = Air

[4] 2.5 Air = Water

For the modern chemist all Plato's reactions are single-reactant reactions when read from left to right; two of them, the third and the fourth, also involve a single reactant when read from right to left; the second and the third are opposite reactions. If we now consider that the fire is represented by a tetrahedron, which is made up by four equilateral triangles, we can represent it as T_4 where T is the symbol of an equilateral triangle. Likewise we can represent air and water with T_8 and T_{20} . Using these symbols we can write the above four reactions as

$$[1] T_{20} = T_4 + 2 T_8$$

$$[2] T_8 = 2 T_4$$

$$[3] 2 T_4 = T_8$$

$$[4] 2.5 T_8 = T_{20}$$

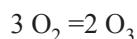
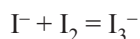
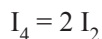
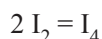
As reported elsewhere (5), the reaction

$$T_{20} = 2 T_8 + T_4 = 5 T_4$$

is a simple combination of reactions [1] and [2], deduced from Plato's above reactions.

Two earlier attempts at writing Plato's reactions in symbolic terms are described in detail on pp 22 and 23 of Ref. 5. Neither conforms to chemists' conventions for formulae and reaction equations—another demonstration of the power of the correct chemical equations symbolism.

The above equations are impressive: we are looking at the first analogues of chemical reactions in the history of science. They are the analogues of chemical reactions such as



Notice that while in chemical reactions masses are conserved, here the areas are conserved; see also p 24 of Ref. 5. There is an isomorphism between masses and areas. Of course these are deductions allowed us by our writing the reactions as modern chemical equations, and Plato didn't know the concept of mass. In these reactions the polyhedra play the role of molecules and the equilateral triangles out of which they are made play the role of atoms. But the analogies with modern science may be carried further. Plato considers his atoms, the equilateral triangles making up tetrahedra, octahedra and icosahedra, and the square making up the cube, made up, in their turn, by two kinds of elementary triangles, the equilateral tri-

angle made up by two right-angled scalene triangles and the square made up by two isosceles triangles (Figure 1).

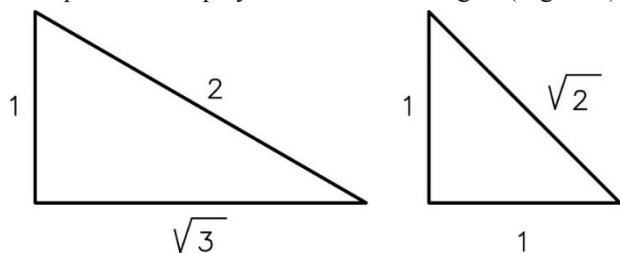


Figure 1. Plato's elementary triangles, from which the faces of his elements are composed.

Can we use the term “chemical” equations for the above “reactions”? I believe we are justified to do so because in Plato's reactions the “atoms” are reshuffled but their nature and their numbers remain the same on both sides of the equations, the nature and the number being here the constitution and the quantity considered by Lavoisier.

In so doing Plato is describing matter at three levels, which, in modern terms are analogous to those of molecules, atoms and sub-atomic particles. Plato considers also “atoms” of different sizes (Figure 2). These atoms of different size have been aptly called “isotopes” by Friedländer (6) because isotopes are atoms of the same nature and different mass while here the “isotopes” are made up by atoms of the same form and different areas. By the way, it is not possible to transform tetrahedra, octahedra and icosahedra into cubes because the cubes are made up by a different atom than the other three polyhedral, but it is possible to transform cubes of one size into cubes of a different size (5).

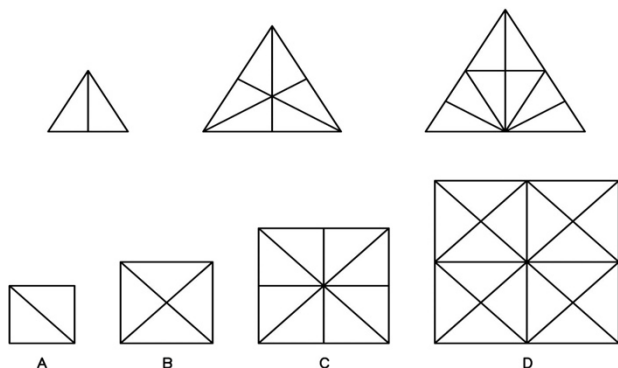


Figure 2. Graded sizes of equilateral triangles and squares.

Leucippus's and Democritus's Atomism Compared to Plato's Geometrical Atomism

Probably every student of physics or of chemistry knows that the concept of atom was created by the an-

cient Greeks Leucippus and Democritus and maybe some also know that they created the concept of void. Russell writes that Leucippus and Democritus “believed that everything is composed of atoms which are physically, but not geometrically, indivisible” and that there was an infinite number of atoms of all possible shapes and size (Ref. 2, Ch. 9). Another character of atoms of the ancient atomists is that they are always in motion, a very modern idea. There were impacts among the atoms

The only thing that atoms do is to move and hit each other, and sometimes to combine when they happen to have shapes that are capable of interlocking.

We see then that Leucippus and Democritus were the first to create the concept of combination of atoms. The above description of Leucippus's and Democritus's theory is just a brief résumé of the beautiful chapter dedicated to the atomists by Russell with a couple of Russell's quotations. In his opinion “The theory of the atomists, in fact, was more nearly that of modern science than any other theory propounded in antiquity.”

Plato didn't have or he didn't accept the concept of void (Ref. 3, 79bc and 80c on pp 81-82). This is not surprising because, as Russell writes (Ref. 2, p. 72),

Plato never mentions Democritus in the Dialogues, but is said by Diogenes Laertius to have disliked him so much that he wished all his books burnt.

Nevertheless, Plato's geometrical atomism with its limited number of atoms of a well specified nature is closer to our idea of atoms. Moreover Plato introduces the new idea of intertransformability of elementary corpuscles and with that the first chemical reactions of history. His theory is also the first mathematical description of the structure of matter in history and we have seen that mapping his theory in modern terms it appears also as describing the matter at the molecular, atomic and sub-atomic levels. Of course one may ask why Plato after having introduced his two atoms, the equilateral triangle and the square, considered the elementary triangles described above. This point is discussed in Ref. 7.

Heisenberg compared Democritean and Platonic atomisms (8):

In the philosophy of Democritus the atoms are eternal and indestructible units of matter, they can never be transformed into each other. With regard to this question modern physics takes a definite stand against the materialism of Democritus and for Plato and the Pythagoreans. The elementary particles are certainly not eternal and indestructible units of matter, they can actually be transformed into each other... But the resemblance of the modern view to those of

Plato and the Pythagoreans can be carried somewhat further. The elementary particles of Plato's *Timaeus* are finally not substance but mathematical forms. "All things are numbers" is a sentence attributed to Pythagoras. The only mathematical forms available at that time were such geometrical forms as the regular solids or the triangles which form their surface. In modern quantum theory there can be no doubt that the elementary particles will finally also be mathematical forms, but of a much more complicated nature. The Greek philosophers thought of static forms and found them in the regular solids. Modern science, however, has from its beginning in the sixteenth and seventeenth centuries started from the dynamic problem. The constant element in physics since Newton is not a configuration or a geometrical form, but a dynamical law.

Moreover, Heisenberg highly valued the introduction of symmetry in Platonic atomism because Plato's atoms are symmetrical objects (9): "In the beginning was symmetry! This sounded like Plato's *Timaeus*." More recently, physics Nobel laureate Frank Wilczek (2004) wrote about the relation between modern physics and Plato's ideas (10):

In its symmetry-based standard model, it would appear, fundamental physics comes closest to achieving the vision of Pythagoras and Plato, a perfect correspondence between what is real and what is mathematically ideal.

Heisenberg, Russell and Wilczek Write about Plato's Reactions

The importance of writing down the reactions using chemical equations, that is of using the modern standard chemical symbolism, can be seen if one considers how Heisenberg describes in words the above reactions. In *Physics and Philosophy* he writes (8, pp 68-69):

If the regular solids, which represent the four elements, can be compared with the atoms at all, it is made clear by Plato that they are not indivisible. Plato constructs the regular solids from two basic triangles, the equilateral and the isosceles triangles, which are put together to form the surface of the solids. Therefore, the elements can (at least partly) be transformed into each other. The regular solids can be taken apart into their triangles and new regular solids can be formed from them. For instance, one tetrahedron and two octahedra can be taken apart into twenty equilateral triangles, which can be recombined to give an icosahedron. That means: one atom of fire and two atoms of air can be combined to give one atom of water.

Heisenberg calls here atoms objects which, as we have seen from the above reactions, correspond more closely to our concept of molecule. Moreover the equilateral triangle, as we have seen from the above reactions, is an atom and not an elementary triangle. For Plato the molecules, not considered by Heisenberg, are made up by atoms represented—we remind the reader—by equilateral triangles which are divisible in their elementary triangles, as modern atoms are divisible in more elementary particles. Thus the two triangles mentioned in the passage above come from different structural levels: the equilateral is a face of some polyhedra, whereas the isosceles is more elementary, from which the faces of cubes are comprised.

Russell writes (2, p 145):

The true elements of the material world, *Timaeus* says, are not earth, air, fire and water, but two sorts of right-angled triangles, the one which is half a square and the one which is half an equilateral triangle ... By means of these two triangles, it is possible to construct four of the five regular solids, and each atom of one of the of the four elements is a regular solid.

Contrary to Heisenberg, Russell rightly describes the two elementary triangles but like Heisenberg he considers as atoms the objects we consider as more analogous to molecules.

Wilczek follows in their steps titling a section of his book *A Beautiful Question* "Platonic Solids as Atoms." Then, coherently with his considering atoms the polyhedra, he interprets the triangles, which we have seen as Plato's analogues to sub-atomic particles, as the equivalents of "quarks and gluons" (11).

Conclusions

We have here a clear demonstration of the fundamental importance of chemical equations that show constitution and quantity. Heisenberg and Russell would have developed a closer analogy to current chemical theory if they had written Plato's reactions as chemical equations. Wilczek perceptively interpreted Plato's model as having three structural levels, but his analogies are more appropriate to particle physics than to chemistry: atoms, sub-atomic particles, and sub-sub-atomic particles.

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10. F. Wilczek, "Physics in 100 Years," *Physics Today*, **2016**, 69(4), 32-39; doi: 10.1063/PT.3.3137 . See also Ref. 7.
11. F. Wilczek, *A Beautiful Question*, Allen Lane, London, 2015, pp 46-49.

About the Author

Francesco Di Giacomo is a retired chemistry professor of the engineering faculty of Sapienza University of Rome. He has published articles of experimental electrochemistry, theoretical chemistry, educational chemistry and history of chemistry. In 2020 he published two books on the Marcus theory of electron transfer reactions.

HIST Elections

The following HIST members were elected in the 2022 divisional elections:

Chair-Elect (term 2023-2024)	Joe S. Jeffers
Secretary/Treasurer (term 2023-2024)	Vera Mainz
Councilor (term 2023-2025)	Roger Egolf
Alternate Councilor (term 2023-2025)	David Lewis
Councilor (term 2024-2026)	Mary Virginia Orna
Alternate Councilor (term 2024-2026)	Christopher Heth

As arranged in previous elections, Arthur Greenberg will begin a two-year term as Chair in 2023 as Seth Rasmussen begins a term as immediate past chair. Daniel Rabinovich's term as immediate past chair ends at the end of 2022.

Congratulations to those elected and thanks to those who are and were willing to serve the division.

ROLE FOR HYPOCHLORITE SAPONIFICATION IN SEMMELWEIS'S SUPPRESSION OF PUERPERAL FEVER EPIDEMICS

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Abstract

The most prominent product of the Vienna General Hospital was Ignaz Semmelweis, who was the first to use a chemical antiseptic to counteract the large scale outbreaks of puerperal fever which had periodically decimated maternity wards ever since those institutions were established. Semmelweis introduced the compulsory use of bleach and nail brushes to wash gynecologists' hands, before patient examinations, to remove pathological material and lubricating oil. He worked with little chemical knowledge and no possible knowledge of microbial pathology in the significant years prior to 1847. He was, strangely by twenty-first-century standards, influenced by ideas of miasmas in his efforts to suppress pathology by suppressing the clinging odor of pathology with chlorine. His chemical breakthrough has saved many thousands of babies' and mothers' lives. It has been assumed that the chemical mechanism for Semmelweis's antiseptic procedure was oxidation. The present work suggests that the striking suppression of puerperal fever was achieved by saponification in addition to oxidation.

Introduction

Ignaz Philipp Semmelweis (1818-1865) (1) was a gynecologist who worked in the *Allgemeines Krankenhaus der Stadt Wien* (Vienna General Hospital) which was and is a prestigious teaching institution. Despite highly qualified and influential medical staff, the hospital, like many lying-in hospitals for pregnant women, was pe-

riodically overwhelmed by outbreaks of puerperal fever which were fatal for large proportions of the mothers and babies occupying the hospital (2). Medical practitioners, including Semmelweis early in his career, had little idea of the cause of puerperal fever, often resorting to concepts we find strange today, such as theories of pathological miasmas (3, 4).

...when the linen and the bedding does not always present the necessary degree of cleanliness; then the air in the wards can become impregnated with decomposed matter, either because the exhalations of the puerperae are not removed by ventilation, or because decomposed matter is carried into the lying-in wards from the general hospital, from the nearby deadhouse, [or] from the open sewers outside the lying-in hospital ... A locale can only cause childbed fever [puerperal fever] when it is so polluted with decomposed matter that the exhalations of decomposed matter mixed with the atmospheric air penetrates into the genital organs of the patients...

Odors from lesions, death and decay must have been appalling in hospitals of the time, and the high standards of cleanliness practiced now were not seen in the mid nineteenth century. This is shown spectacularly by the observations of Young (5) and Berkeley (6) of repeated *Coprinus* basidiocarp crops growing from a patient's bed. *Coprinus* is a common dung fungus which we assume developed on patient dung seeping through the bed, not cleaned up for as long as the fungus needs for development of fruiting bodies (approximately one week on dung

in the experience of one of us, MW), then developing a second crop from the imperfectly cleaned bed.

By 1847, however, Semmelweis was able to conclude from his observations of the persistent odor of medical practitioners' hands, especially after autopsies, and analysis of his own statistics, that puerperal fever was a nosocomial disease (i.e., acquired in hospitals) which was initiated by transfer of infectious odiferous material of unknown nature from patient to patient by medical workers themselves, causing the intense and destructive but local outbreaks of disease. Localized to patients touched by the medical practitioners, the disease often developed as linear trails of infected patients which traced the path of the doctor moving from patient to patient in the ward some days previously.

Semmelweis's work on disinfection, which was discussed in 1840s Vienna (2) and finally published in 1861, predates publication of Lister's work (7) by two decades and the discovery of *Streptococcus pyogenes* in pathological discharges from puerperal fever patients by Pasteur (8) by more than three decades. This is why it took some time for Semmelweis to discover that pathological material absorbed to skin and the oil used for finger lubrication (9) was a serious danger to patients. Despite Semmelweis's discovery and his suppression of puerperal fever at Vienna he argued with influential proponents of miasma theories and was acrimoniously dismissed (2, 3). It was only after returning to his native Hungary and a long drawn-out process of persuasion and repeated delay that in 1861 the statistics and chemical methods of Semmelweis were widely accepted, especially regarding the suppression of periodic outbreaks of puerperal fever by handwashing and nail scrubbing with calcium hypochlorite, these being summarized in the following circular to district authorities from the Presidential Council of Hungary. His method varied over time, but the following circular is a good summary of the final procedure of Semmelweis (10).

To All Whom It May Concern,

Dr. Ignác Fülöp Semmelweis, Royal Hungarian University Professor, in his excellent book on puerperal fever believes that it is caused by decomposed, organic animal material introduced into the body of parturient women.

Dr. Semmelweis's opinion is embraced by the medical faculty of the Royal Hungarian University and is shared by the best scientists and physicians.

There can be no other reasonable prophylactic method than to prevent the introduction of any infectious, decomposed material into the body of the

lying-in patient. For this reason, the author proposes that physicians and midwives, before touching any infectious agent, should oil their hands profusely, in order to prevent the material from penetrating into the pores of the skin. Subsequently, by washing their hands well with soap and chlorine (*chlorniturn calcis* [sic (11)]) to neutralize any remaining infectious substance, they should go on doing this until they find their hands smooth and **slippery** [emphasis added].

By this method the hands can be made perfectly clean. It should however be remembered that infection can be introduced not only by means of the examining fingers, but also through any objects infected by contact with decomposed animal material. Consequently, these must also be disinfected before being brought into contact with the genital organs, or else should be discarded: such objects can be surgical instruments, bed-clothes, sponges, etc.

As the infectious substances can be carried over by air too, it is imperative that the wards should be well and frequently aired and that exhalations and exudations should be removed before decomposition.

These preventive measures which have been examined and found indispensable should be introduced and observed in hospitals, obstetric and lying-in wards and in private practice. Therefore, we call upon all officials to advise physicians, surgeons, obstetricians and midwives to study the prophylactic measures proposed by Prof. Semmelweis in his book on puerperal fever and to introduce them in hospitals and elsewhere.

September 1st, 1862

Semmelweis recognized a requirement to break down, destroy or remove pathological matter, even before *Streptococcus pyogenes* was recognized as the principal cause of puerperal fever (8). Modern scientists, who are familiar with the work of Pasteur and Koch (12) and Duchesne (13), associate infectious pathology with cellular parasites including airborne suspensions of bacteria. This is something that adds confusion to readers of Semmelweis because he was a miasma theorist and when he wrote of airborne particles he meant chemical particles while later readers may mistakenly assume the particles he referred to were bacteria not molecules. The influence of miasma theory on Semmelweis was fortunate for his patients, because it led to his use of molecules that suppress chemical odors very well by chemical reaction (sometimes using dissolved dichlorine gas and sometimes calcium hypochlorite). Semmelweis used the benchmark of odor to judge if pathological cadaverous matter had been destroyed. He destroyed the odor intentionally but also unintentionally destroyed bacteria. This is a great example of correlation without causation which had a co-

incidental good effect of correctly directing future action.

Nobody can suggest a precise mechanism which accounts for his chemical disinfection except general destruction of organic matter and damage to a complex mechanism (pathogens), where the form of damage is too difficult to describe. It has been assumed that Semmelweis achieved effective hand sanitization in two broad ways. One was by oxidation reactions (summarized in 14) which killed bacteria, especially *Streptococcus pyogenes*. This was supplemented by scrubbing, which dislodged pathological matter and created a larger surface area for oxidation, especially for matter trapped under fingernails. Semmelweis's sanitization method has an additional sign that is often ignored, which is to keep washing until hands felt slippery. This suggests that an additional, third part of his sanitation method is important, i.e., saponification of the physician's own natural oils and lubricant oil to make soapy material felt by gynecologists as slippery when they washed their hands with hypochlorite. Saponification is important here because it turns oils to soaps and while soaps do not have strong antiseptic properties they instead emulsify fats and oils. This dislodges bacteria and causes degerming of skin (15). We suggest that the use of oil (presumably triglycerides), followed by soap and hypochlorite caused this additional component of sanitation. Handwashing was enhanced by saponification of oil which increased soap in the wash mixture and undermined attached pathogens. This is useful because pathogens adhering to skin or under oil may be easily washed away down the drain in this process.

To achieve chemical disinfection Semmelweis used *chlorina liquida* (6% w/v chlorine gas in water (16)) in his earlier work or chlorinated lime (17) in his later work. A conspicuous and unique feature of modern domestic bleach is that it makes hands feel very slippery immediately and in a way that is unique. It is perceived differently to the slipperiness of lubricating oil or of ordinary soap. This is presumably due to autosaponification. Modern household bleach has a high pH (around 12, (18)), which might cause saponification, but we suspected that this does not account for all the phenomena seen by Semmelweis, especially as *chlorina liquida* was an effective disinfectant.

The use of oil in gynecology gave us a technical advantage in solving this question, namely that lubricating oil is much more uniform than human skin lipids so analysis using infrared (IR) spectroscopy was a possibility for testing our ideas. We used commercial soybean oil, which we assume is similar to that used for lubrication in nineteenth-century gynecology (9), to react with domes-

tic bleach to determine if saponification of triglycerides by hypochlorite can take place under conditions similar to Semmelweis's procedure for hand washing.

Methods

We have examined the method of hypochlorite disinfection ourselves. While many researchers have reacted chlorine and hydrocarbons using rigorous chemical methods including high temperatures or with a catalyst (19) we assumed these experiments were not relevant to hospital disinfection. It is important that all these methods were conducted at room temperature. The bleach solution used contained 6.9% sodium hypochlorite and had 5.7% available chlorine (Walmart, Bentonville, Arkansas). Commercial food grade soybean oil was used (Publix, Lakeland, Florida). Oil (20 mL, 15.044 g) and bleach (20 mL) were added to a 50 mL Falcon tube and shaken to an emulsion by hand. The mixture was incubated at 25 °C for 2 weeks and white solid saponified material accumulated at the interface. This time was used to observe that no more saponified material appeared and we assumed that reaction had run to completion. The mixture was then centrifuged at 5000 g for 10 minutes. The interface material was a firm white slippery solid. The upper oil layer, white interface material and lower aqueous layer were removed and stored separately. Water adhering to the interface material was viscous. This viscous material had air introduced into it using a 1-mL pipette tip and lingering bubbles were produced. A small amount was transferred to a 1.5-mL Eppendorf tube and shaken by hand. Foam was produced. The white solid was washed with 2 × 2 mL water then air dried for 14 days yielding 13.4 mg of material. There was presumably additional saponified material which was soluble in the aqueous and oily phases but not harvested.

Infrared spectra (Figure 1) were recorded using a Perkin Elmer Spectrum One FT-IR equipped with ATR. NMR spectra were recorded using the soluble portion of the acidified white solid material in CDCl₃. Briefly, white solid (10 mg) was suspended in 0.7 mL of D₂O and 20 µL of 20% DCl in D₂O was added to the mixture. CDCl₃ (0.6 mL) was added to the mixture. This was allowed to separate at room temperature for 15 minutes, giving an upper aqueous layer, and lower CDCl₃ layer with undissolved white solid suspended between these two layers. The bottom layer (CDCl₃) was pipetted out and filtered through an anhydrous Na₂SO₄/glass wool short column directly to an NMR tube. The ¹H NMR spectra were obtained using a Bruker Avance 400 MHz device (Figure 2).

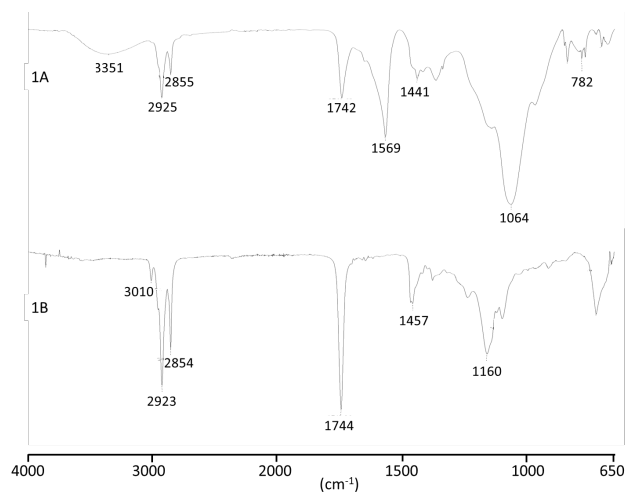


Figure 1. A) IR spectrum of the white solid precipitated in water layer. B) IR spectrum of soybean oil.

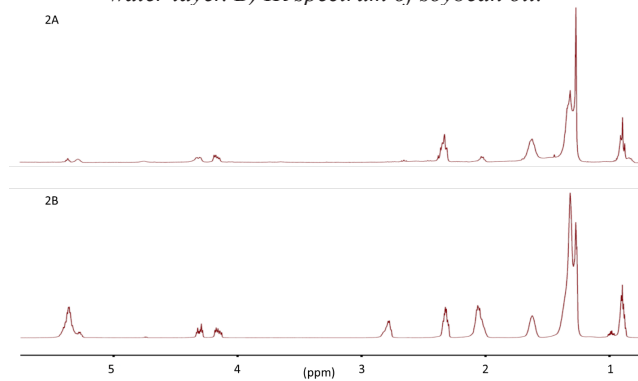
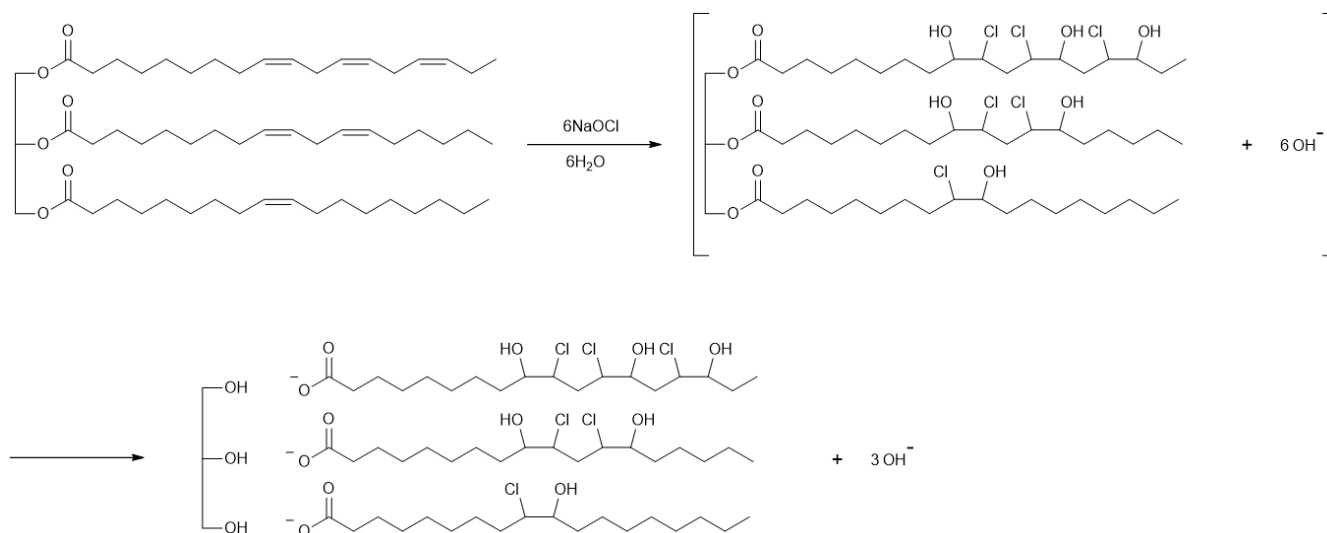


Figure 2. A) NMR spectrum of the protonated white solid. B) NMR spectrum of soybean oil.

Results and Discussion

It was surprisingly easy to produce a solid soap using oil and hypochlorite (Scheme 1), and this material was recovered easily by pulling the solid out of the reaction vessel (50-mL Falcon tube) and blotting to remove excess liquid aqueous and oily material. The IR spectrum of this white solid soap supports the idea that triglycerides underwent saponification to form the carboxylate of fatty acids as seen in figure 1A which shows the IR spectrum of the white solid material. A broad band at 3100–3700 cm^{-1} is attributed to the O–H stretching of alcohol. The bands at 1569 and 1441 cm^{-1} are attributed to asymmetric and symmetric COO^- stretching. The band at 782 cm^{-1} is attributed to C–Cl stretching. A comparison between IR spectrum of the white solid (Figure 1A) and that of soybean oil (Figure 1B) shows disappearance of C–H stretching of sp^2 carbons at 3010 cm^{-1} . The spectrum also reveals that unsaturated bonds were oxidized by hypochlorite to yield chloro- and hydroxy- groups.

Figure 2A shows ^1H NMR spectrum of the mixture in CDCl_3 layer. A comparison between ^1H NMR spectrum of the protonated white solid soap (Figure 2A) and that of soybean oil (Figure 2B) shows disappearance of CH (5.37 ppm) of sp^2 carbons at the unsaturation points and CH_2 (2.78 and 2.06 ppm) next to the sp^2 carbons. This supports the conclusion that these double bonds have been replaced with hydroxyl groups or chlorine atoms.



Scheme 1. The reaction shows a triglyceride containing oleic acid (C18:1), linoleic acid (C18:2) and linolenic acid (C18:3) as a representation of soybean oil. First step, unsaturated bonds of the triglyceride are oxidized by sodium hypochlorite and water from bleach solution to yield chlorides and hydroxyl groups along with hydroxide ions. Second-step, base promoted saponification occurs to yield glycerol and carboxylates of fatty acids.

From all of this we suggest an additional component to Semmelweis's method of sanitation where the mechanism of oxidation was previously assumed to account for his success. This additional component is that saponification is important to the process especially because in the nineteenth century gynecologists' fingers were lubricated with oil. Saponification is important because it breaks the oil into soluble products and undermines attachment of pathological bacteria. These saponification reactions are relevant because hypochlorite and oil can readily form soap seen in the form of white solid material and felt as slippery.

This disinfection method was overtaken later by other methods and materials, such as washing with carbolic soap (20, 21), partly because Semmelweis was very slow to publish his work. Also, hypochlorite hand-washing is an uncomfortable process (22), causing skin irritation, eyewatering and nausea in the experience of one of us (MW). This made the process unpopular with some of Semmelweis's colleagues who resisted his efforts effectively (2).

To some flattering later historians (2) Semmelweis's work is viewed as a step in the inevitable path to the modern age and a great example of early and saintly scientific success. Semmelweis was successful in suppression of puerperal fever while he worked in Vienna and also in hospitals he worked in later. However, his work was disconnected from later achievements in microbiology, such as those of Pasteur, Koch and Lister, and largely ignored from the late 1840s to the early 1960s. This was because several factors operated against him. He was very slow to publish: work done in 1847 was only published in book form in 1861. There were some brief descriptions of his Vienna work by colleagues but fourteen years is a long time to wait for details! He was also marginalized by clashes with colleagues and senior members of his profession, on subjects medical, political and emotional (23). Those clashes escalated to the point of him abruptly leaving Vienna (1850), the place where his work was discussed and written of, to a small degree, in German. He returned to Pest in his native Hungary, where his work was then discussed in Hungarian, which is a much less accessible language to most scientists. Since 1850 Semmelweis was admired in Hungary but neglected elsewhere. However, in 1966 Semmelweis's work was revived as an influential example (24) and he has since been portrayed as a scientist of great achievement (2). Nevertheless, detailed reading shows some complexity and feet of clay. He was dogmatic, but changed his dogma three times (25), to the exasperation

of his contemporaries. This dogmatism included verbal anger and ultimately writing, in the form of insulting open letters to his fellow gynecologists (3). Recently he has taken on the additional reputation of a martyred saint because as his behavior became more and more alarming to his relatives and friends he was tricked into captivity in a mental hospital where the warders, following the standards of the time, beat him severely. Semmelweis contracted sepsis from one of the wounds and ironically died of septic disease similar to puerperal fever (26).

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About the Authors

Michael Witty is still an empirical scientist, publishing from 1989 in ecology, botany, zoology, human pathology, biotechnology, microbiology, microscopy, molecular biology, biochemistry, organic chemistry, inorganic chemistry, crystallography, scientific education, intellectual property, history, English and ancient literature. He has lived or worked on every continent except Antarctica, which would be absurd.

Theppawut Ayudhya practices syntheses focusing on polymer materials, inorganic synthesis, and his research involves a wide range of applications from medicine, chemical sensors, to energy storage materials.

2022 Sarton Medalist

Margaret W. Rossiter has been named the 2022 Sarton Medalist by the History of Science Society (HSS). Rossiter is best known for her work on women in science and the structural inequalities under which they have worked or been excluded. Those inequalities were documented in her three-volume *Women Scientists in America* as well as in influential articles such as "The ~~Matthew~~ Matilda Effect in Science." Her work has been used by policy groups such as the US National Science Foundation to understand barriers to participation and promote inclusion of women in science, and Rossiter herself has worked on issues of inclusion with the American Association for the Advancement of Science (AAAS), the Fulbright Foundation and the National Institutes of Health.

Rossiter earned an A. M. from Radcliffe College, an M. S. from the University of Wisconsin-Madison, and an M. Phil. and Ph.D. from Yale University. She is Marie Underhill Noll Professor of History of Science Emerita at Cornell University. She served HSS as a co-founder of its Women's Caucus and as editor of both *Isis* and *Osiris*. She has been previously named a Guggenheim Fellow, a MacArthur Fellow and a Fellow of the AAAS.

This item drew on information in Jessica Ratcliff's blog post at <https://hssonline.org/blogpost/1987463/475363/Margaret-W-Rossiter-2022-Sarton-Medalist>.

THE TROUBLE WITH THERMODYNAMICS

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There is an anecdote attributed to the famous German theoretical physicist, Arnold Sommerfeld (Figure 1), dealing with the problem of how one learns the rudiments of thermodynamics (1):

Thermodynamics is a funny subject. The first time you go through it, you don't understand it at all. The second time you go through it, you think you understand it, except for one or two points. The third time you go through it, you know you don't understand it, but by that time you are so used to the subject, it doesn't bother you anymore.

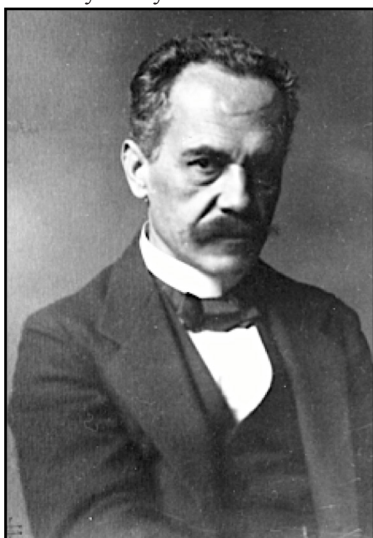


Figure 1. Arnold Sommerfeld (1868-1951). All figures are courtesy of the Oesper Collections in the History of Chemistry, University of Cincinnati.

The equally famous German physical chemist, Wilhelm Ostwald (Figure 2), tended to agree (2):

... thermodynamics, like Sleeping Beauty, was surrounded by hedgerows bristling with impenetrable mathematical thorns ... I can still remember the inner struggle I underwent as I tried to grasp thermodynamics, as it was called then, or energetics as I now refer to it today.



Figure 2. Wilhelm Ostwald (1852-1932)

Less diplomatic was the comment of Louis Kahlenberg of the University of Wisconsin (Figure 3), who, despite having received his Ph.D. under Ostwald at Leipzig, became a determined opponent of both the ionic

theory of dissociation and the use of thermodynamics or “thermodihumbug,” as he called it, in chemistry (3):

Thermodynamics is all right for studying steam engines. It is the greatest humbug ever to go up.

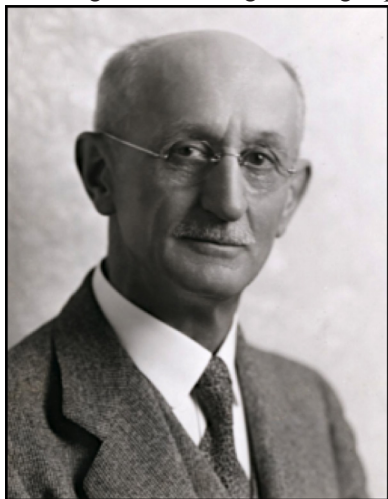


Figure 3. Louis Kahlenberg (1870-1941)

The Trouble with Entropy and the Second Law

Much of the problem with mastering thermodynamics seems to have centered on the concept of entropy increase and the second law, which Kahlenberg dismissed with the comment that (3):

The second law of thermodynamics simply means that water won't flow up hill.

Ostwald also admitted to having difficulties with the law (2):

How often back then did I take long walks alone so as to have a chance to think undisturbed about the second law ... It was at that time extremely difficult to realize what Clausius' law of the increase of entropy or William Thomson's law of the dissipation of energy had to do with the calculation of the latent heat of vaporization from the temperature coefficients of steam pressure.

Though thermodynamics was a brain child of the steam engine, many engineers had trouble, like the chemists, with the entropy concept. Thus the British engineer, James Swinburne (Figure 4), lamented in 1903 that (4):

As a young man I tried to read thermodynamics, but I always came up against entropy as a brick wall that stopped my further progress. I found the ordinary mathematical explanation, of course, but no sort of physical idea underlying it. No author seemed even to try and give any physical idea. Having in those days great respect for textbooks, I concluded that the

physical meaning must be so obvious that it needs no explanation and that I was especially stupid in that particular subject ... After a few years I would tackle the subject again, and always I was brought up dead by the idea of entropy. I asked other people, but I never met anyone who could tell me, and I met one—an engineer—who admitted he did not know.



Figure 4. James Swinburne (1858-1958)

Indeed, some engineers went so far as to either ignore or even deny the validity of the second law. Thus in 1879, Henry T. Eddy (Figure 5), the first Professor of Engineering at the University of Cincinnati, invoked three, rather than two, basic laws of thermodynamics in his textbook on the subject, not one of which mentioned entropy increase, even though Clausius was quoted throughout the text on other subjects (5). As far as I can determine from his rather confusing presentation, Eddy seems to have thought that Carnot's cycle was the second law, even though it only applies to ideally reversible heat engines and thus does not involve the net entropy increase demanded by Clausius' version of the second law.

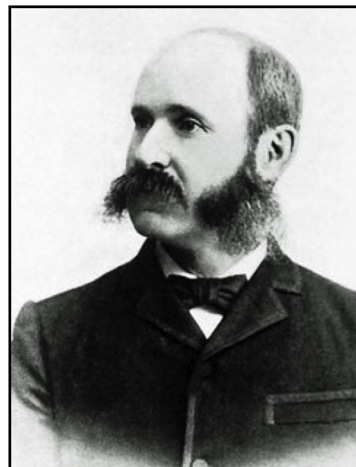


Figure 5. Henry Turner Eddy (1844-1921)

Even more explicit was Sidney A. Reeve, Professor of Steam-Engineering and Hydraulics at the Worcester Polytechnic Institute, who, in his 1903 monograph, *The Thermodynamics of Heat-Engines*, referred to “the so-called law of the dissipation of energy,” followed by his personal paraphrase of Clausius’ second law (6):

The entropy of the world tends to a maximum and the temperature to a minimum.

which, in turn, was followed by the alternative:

The total entropy and the average temperature of the universe remain constant.

Reeve expressed doubts that either of these statements was true. His reason was his belief that entropy applied only to heat energy and since heat was but one of many kinds of energy, it was doubtful that it applied to the universe as a whole. This was further coupled to his belief that entropy was simply the capacity factor for heat energy, just as mass was for gravitational energy and electrical charge was for electrical energy, and that it, like the latter two, was conserved. He even went beyond Eddy’s three laws of thermodynamics and postulated four laws, the third and fourth of which dealt with various temperature-entropy cycles, of which the third was again Carnot’s idealized cycle.

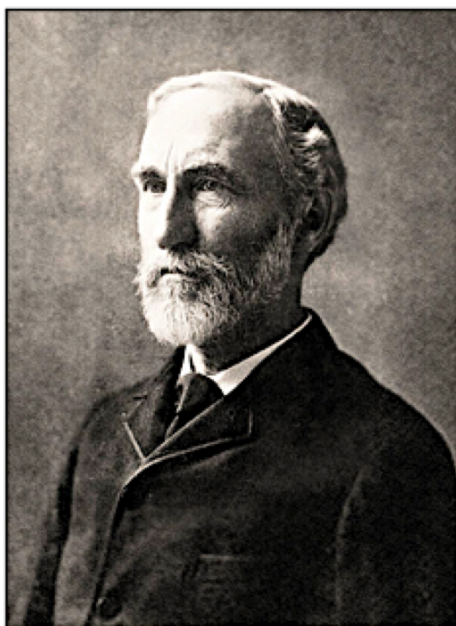


Figure 6. Josiah Willard Gibbs (1839-1903)

The Trouble with Gibbs

Yet another difficulty, at least for the average chemist with limited mathematical training, was the extensive use of mathematics in most treatises on thermodynamics—those “hedgerows bristling with impenetrable mathematical thorns,” that Ostwald had mentioned. Nowhere was this more obvious than in the reception accorded the work of the American physicist, Josiah Willard Gibbs (Figure 6), whose memoir “On the Equilibrium of Heterogeneous Substances,” published in installments in the *Proceedings of the Connecticut Academy of Arts and Sciences* in the period 1876-1878, is now considered one of the most significant scientific papers published in the 19th century (7).

Not only were problems created by Gibbs’ choice of an obscure journal in which to publish his epic memoir, but also by his dense mathematical presentation of his results. This is confirmed by Ostwald’s first encounter with Gibbs’ work (2):

Gibbs, for his part, had so successfully buried the results of his monumental research in the inaccessible journal of a provincial scientific academy that it required no small effort (in which I was involved) to bring them back into the light of the scientific record ... I managed, not without considerable difficulty, to obtain these papers and study them ... I found them hard to read, but recognized, without any doubt, their great importance.

To solve these difficulties, Ostwald decided to publish a German translation of Gibbs’ memoir (2, 8):

I found no better way to get to the heart of the matter than to translate the publications word for word. They certainly couldn’t be summarized because they were written in such a condensed form. I thought that by bringing out a German edition. I could do my part to rescue these long overlooked treasures and make them available as common currency ...

The dense nature of Gibbs’ work was also noted by the famous British physicist, Lord Rayleigh (Figure 7), when in 1892 he wrote to Gibbs (9):

Have you ever thought of bringing out a new edition of, or a treatise founded upon, your “Equilibrium of Heterogeneous Substances?” The original, though now attracting attention, is too condensed and too difficult for most, I might say all readers.

to which Gibbs replied:

I thank you very much for your kind interest in my “Equilibrium of Heterogeneous Substances.” I myself had come to the conclusion that the fault was that it was too long. I do not think I had any sense of the value of time, of my own or others, when I wrote it.

In fact, in 1878 Gibbs had already published a condensation of his memoir (10) and in 1919 a French condensation would also appear (11).

Even more shocking was the correspondence between Rayleigh and Lord Kelvin (Figure 7), one of the founders of the second law of thermodynamics, in which Kelvin admitted that he could find nothing of value in Gibbs’ memoir (9):

I feel very doubtful as to the merit of Willard Gibbs' applications of the "Second Law of Thermodynamics" ... Do you attribute merit to them?

Followed in a later letter by his final conclusion that:

I find no light for either chemistry or thermodynamics in Willard Gibbs.

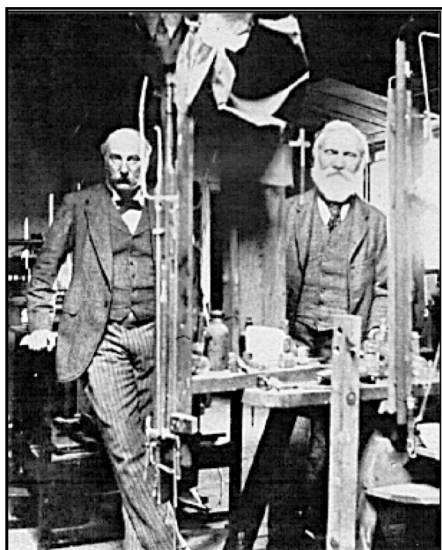


Figure 7. Right: Lord Rayleigh (1842-1919). Left: Lord Kelvin (1824-1907).

Perhaps the best summary of both the impact and problems produced by Gibbs was given by Wilder D. Bancroft (Figure 8), Professor of Physical Chemistry at Cornell, founder of the *Journal of Physical Chemistry*, and, like Kahlenberg, a former student of Ostwald (12):

The famous monograph on equilibrium in heterogeneous systems by J. Willard Gibbs is in some respects one of the most remarkable scientific articles that has ever been written. Gibbs was possessed of marvelous and apparently unerring insight, but the gift of expression was denied to him. It is not too much to say that Gibbs wrote in hieroglyphics and that a great part of his manuscript is still undeciphered. We know now that we can find in it the chemical potential, the phase rule, and the theory of osmotic pressure; the theory of electromotive forces, the Donnan equilibrium, and the theory of emulsification. We feel certain that some day we shall find in it theories in regard to all sorts of other things; but we do not know when we shall find them. It used to be popular to ascribe the negligible influence which Gibbs then had on the development of physical chemistry to the fact that his monograph was published in the Transactions of the Connecticut Academy, but this fiction cannot be maintained. Everyone knows about Gibbs now; but the only way that one can find anything new in Gibbs is to discover it independently and then look it up in Gibbs.



Figure 8. Wilder D. Bancroft (1867-1953)

The Trouble with Ideality

A final difficulty was the gradual recognition that most of the laws of the newly emerging discipline of physical chemistry, such as the determination of equilibrium constants, the depression of solution freezing points and the elevation of boiling points, the Nernst equation, and the calculation of osmotic pressures, were rigorously true only for highly diluted solutions, causing one writer to define the field as "the chemistry of slightly impure water" or, as Bancroft preferred, the study of "slightly polluted water."

As usual, Kahlenberg was less diplomatic when he stated in his lecture notes that (3):

Infinitely diluted solutions = Infinitely concentrated humbug

Nor was Bancroft impressed by G. N. Lewis' attempt to deal with this problem via his introduction of such concepts as fugacity and activity. Indeed, he would satirize the latter concept with the observation that (13):

We can always make the experimental data agree with the theoretical values by multiplying the data by the ratio of the theoretical values to the experimental values.

leading to his infamous final characterization (13):

We might remember Mrs. Eddy and G. N. Lewis as the Gold Dust Twins of Christian and Physical Science. Mrs. Eddy eliminates sickness but admits error. Lewis admits sickness but eliminates error.

Or as the historian, John Servos, has phrased it (14),

Lewis' distinction between concentrations and activities was simply a fig leaf concealing physical chemists' ignorance.

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William B. Jensen is professor emeritus of chemistry at the University of Cincinnati, where he was Oesper Professor of the History of Chemistry and Chemical Education and curator of the Oesper Collections in the History of Chemistry. He was founding editor of the *Bulletin for the History of Chemistry*.

Chemistry and Inuit Life and Culture

Chem 13 News, published by the University of Waterloo (Ontario, Canada) devoted a special issue in Fall 2022 to chemistry and Inuit life and culture. Its twelve wonderful pieces from Chaim Christiana Andersen, Rosalina Naqitarvik and Geoff Rayner-Canham on the chemistry behind the traditional knowledge of the Inuit People are accessible online at <https://uwaterloo.ca/chem13-news-magazine/fall-2022-special-edition/feature/chemistry-and-inuit-life-and-culture>.

DEVELOPMENT OF CHEMISTRY AT OHIO UNIVERSITY AND ITS FIRST WOMEN GRADUATES

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Abstract

In the first 100 years at Ohio University nearly 700 bachelor's degrees were awarded by the institution. Only two chemistry-related degrees were earned by women, both in 1903, who wrote Bachelor of Philosophy (Ph.B.) theses on derivatives of hydrocarbons. Why was this significant? A short background on the university, notable milestones, and the development of the chemistry curriculum is given prior to the discussion of the theses written by Ethel Riley and Nannie Nease and their subsequent lives. A discussion of baccalaureate origins of women in chemistry in Ohio shows a dearth of degrees prior to 1920 and thus the significance of the theses written by Riley and Nease.

Background and Introduction

Ohio University traces its origin to the Northwest Ordinance of 1787 and the settlement and government of the territory which provided in Article 3 that "Religion, morality and knowledge, being necessary to good government and the happiness of mankind, schools and the means of education shall forever be encouraged" (1). On January 9, 1802, the Ohio Territorial General Assembly chartered the American Western University and subsequently, on February 18, 1804, the Ohio General Assembly rechartered (2).

the "Ohio University" for the instruction of youth in the various branches of liberal arts and sciences, for the promotion of good education, virtue, religion

and morality, and for conferring all the degrees and literary honors granted in similar institutions.

The course of instruction was laid down on June 9, 1808, and instruction began in the Academy building on June 1, 1809, to three students (3). The first two degrees were conferred in 1815 to Thomas Ewing (1789-1871) and John Hunter. After practicing law in Lancaster, Ohio, Ewing served as a US Senator, Secretary of the US Treasury and the first US Secretary of Interior. Hunter died in Pickaway County, Ohio, in 1816.

Other notable milestones for graduates of Ohio University include the following. On September 17, 1828, the A.B. degree was conferred on John Newton Templeton (ca. 1805-?), an emancipated slave born in South Carolina, its first African American graduate and probably only the fourth in the nation. Templeton went on to become the first teacher, and later principal, of Pittsburgh's first African American school. Athens County native Margaret Boyd (1846-1905) received her B.A. degree on June 26, 1873, and became the first woman to graduate from Ohio University (3). She became a teacher for two years in Monroeville, Ohio, at Cincinnati Wesleyan College in 1875, and in Martinsville, Indiana, from 1880-1884. She returned to Athens as the high school assistant principal from 1884-1898. As enrollment of women increased, Miss Cynthia U. Weld (1838-1915), a New York native, was appointed the first female professor in 1883, teaching English literature, history and rhetoric. Less than a year later, she became the second woman on the faculty at Ohio State University in

Columbus and held the rank of assistant professor there for two years. Saki Taro Murayama from Japan played football and became Ohio University's first international alumnus on June 27, 1895, earning his B.S. degree (4, 5). After graduation Murayama returned to Japan where he became chief engineer of the Japanese branch of Siemens Schuckert (Berlin).

In 1822 the curriculum included science classes in anatomy, mineralogy, botany, and "chymistry" (5). The first professor of natural science was Samuel D. Hoge, A.M. (1792-1826) serving from 1823 to 1826. In 1831, seniors' study included chemistry among several moral and natural sciences (6). In the 1843 Catalogue a college course in chemistry was offered in the second term of the junior year with William Williams Mather, A.M. (1804-1859) as Professor of Chemistry and Natural History (7). Most alumni of Ohio University in the first three decades of degree granting became predominantly lawyers or ministers, with a few who entered teaching or business (8). The earliest known graduate who had an affiliation in chemistry was Zanesville, Ohio native James Merrill Safford (A.B., 1844; A.M. 1848; Ph.D., 1868, Yale; M.D., 1872, Nashville) (1822-1907) who was appointed Professor of Chemistry, Mineralogy, and Geology etc., at Cumberland University in Lebanon, Tennessee, in June 1848 (9).

Chemistry classes were taught in the central building (what is now called Cutler Hall). The labs had been upgraded during the mid-1880s by purchasing \$3,500 in equipment (10). Electric room lighting and both hot air and electricity for the lab benches were added in the late 1880s (11).

In the mid-nineteenth century with the passage of the Morrill Land Grant Act of 1862 and the end of the Civil War, the classical curriculum began to be replaced. Agricultural and mechanical arts took hold. The Hatch Act in 1887 promoting agricultural research and the emergence of electrical engineering stimulated mathematical and science instruction. Graduate education and research emerged (12).

Chemistry at Ohio University, 1892-1903

At Ohio University, Wilbur Morris Stine (1863-1934), B.Ph., 1886, Dickinson College, who had been appointed an instructor in 1886 became the first distinct Professor of Chemistry in 1889. Stine was awarded the Sc.M. and the Sc.D. (*a examinatione*) in 1889 and 1893, respectively, also from Dickinson (13, 14). In 1893 Stine

was awarded a Ph.D. for Merit from Ohio University and became Professor of Physics (15).

Stine left Ohio University in 1893 to serve as Director of Electrical Engineering at the Armour Institute of Technology in Chicago. Probably, the first identifiable degrees in chemistry were earned by William Alfred Westervelt (A. B., 1891; A. M., 1894) and John Edwin Snow (B. S. 1892, M.S. 1896, A.M. Honorary, 1904). Westervelt served as Demonstrator of Chemistry at the Medical College of Indianapolis from 1891-1893 and became a physician. With the establishment of the stand-alone Department of Chemistry in 1892-1893, the Board of Trustees was unsuccessful in hiring James H. Beal, Ph.D., as Professor of Chemistry (16). Thus, Snow was appointed to serve as Professor of Chemistry for one year during 1892-93. He then became Assistant Professor of Physics and Electrical Engineering for 1893-94 before joining Stine at the Armour Institute in Chicago.

In Fall 1893, Walker Bowman (1864-1946), Ph.D., 1888, University of Berlin, became Professor of Chemistry. Bowman had studied under Carl Liebermann with the thesis title "Ueber Reductionsproducte des Anthrachinons und dessen Derivate" (17). He came to Ohio from the Virginia Agricultural and Mechanical College, Experiment Station where he had worked on field tests with tomatoes and the composition and analysis of feed stuffs.

The use of students as laboratory assistants became a common practice with the establishment of the department. In 1895, Allen Bargas, Ph.B, 1893, was employed by Bowman (18). Further, students who were granted a university scholarship would be required to teach one hour per week, although it is not clear whether this was in the laboratory or a lecture (19). Bowman left Ohio University in 1896 to work as a chemist of a tobacco exporting company in Louisville, Kentucky.

Over the next four years, three men would be appointed as Professor of Chemistry. In 1896 Irving Wetherbee Fay (1861-1936), A.B., 1886, magna cum laude, Harvard; Ph.D., 1896, University of Berlin, was appointed Professor. During Fay's one year stay at the university, Hiram Roy Wilson, A.B., 1896, was employed as the student assistant in chemistry and German (20). Wilson would go on to become a noted Professor of English at Ohio University. Fay left the university for the Polytechnic Institute of Brooklyn where he was Professor of Chemistry.

Fay was succeeded by Professor William Edwards Henderson (1870-1962), B.A., 1891, College of Wooster, A.M., 1894; Ph.D., 1897, Johns Hopkins University. Henderson's advisor had been Ira Remsen on the subject of "A Further Investigation of the Symmetrical Chloride of Para-Nitro-Ortho-Sulpho-Benzoic Acid" (21). In his two-year stay, Henderson restructured the chemistry curriculum and instituted laboratory examinations.

Henderson left the university in 1899 for a position at Ohio State University where he moved through the professorial ranks and eventually served as Dean of the College of Arts and Sciences from 1921 to 1927. Henderson's replacement at Ohio University was an organic chemist, John Percival Sylvester, who had earned the Ph.D. in 1899 at Harvard University under Henry Barker Hill. Sylvester left after one year and became manager of the Sylvester Company in Massachusetts engaged in the manufacture of iron products.

In 1900 William Burdelle Bentley (1866-1945), A.B., 1889, A.M., 1890, Ph. D., 1898, Harvard University, arrived in Athens. Bentley's dissertation work had been completed under Charles Loring Jackson with the title "Tribrombenzol and Derivatives" (22). His thirty-six-year tenure at Ohio University stabilized the department while leading it into the mid-twentieth century.

In the 1900-01 Catalog, Bentley explicitly stated his two goals were to acquaint students with the general principles of chemistry and to give students laboratory experience. To accomplish these goals, he expanded the curriculum in both advanced practical and technical chemistry (23).

Since the time of Margaret Boyd, the enrollment of women students—at Ohio University, within the state of Ohio, and nationally—had increased significantly. At the turn of the twentieth century the student population at Ohio University was around two-fifths female out of an average total enrollment of 230, but the number of chemistry-affiliated men and women remained small, typically one or two. Thomas Henry Sheldon earned the B.S. in 1900 and Jacob Claire Evans earned the A.B. in 1901. Commencement in June 1903 saw the first women earn the Ph.B. degree having written chemistry-related theses.

Ethel Eleanor Riley and Nannie Louise Nease, Ph.B., 1903

Ethel Eleanor Riley (1880-11/5/1944) entered Ohio University in the Fall term 1894 in the Prepara-

tory Department at the age of 14 years. Ethel was a native of Guysville in Athens County from a family of seven children, all but one of whom would attend Ohio University. The Preparatory Department was designed to prepare students for regular courses over a three-year period with Fall, Winter and Spring terms (with an optional summer term) each following either a classical, philosophical, scientific, or pedagogical path. Much of the instruction was given by the regular college faculty. At the matriculation of Riley, all paths required arithmetic, physical geography, algebra, and plane geometry. In addition, the classical, philosophical, and science paths required elementary physics, zoology or astronomy, while the pedagogical path required psychology, physiology, chemistry and botany which were taught in the third year (24). It appears that Riley mostly followed the pedagogical preparatory course. However, the sequence of course completion did not necessarily follow the order in the conspectus of classes. Also, it appears that she was absent for a few terms. Fall term 1899/Winter term 1900 appears to be the year Riley transitioned to the Collegiate Department. To earn the A.B. degree required one chemistry course, while both the Ph.B. and B.S. degree required two chemistry courses (25). The only known extra-curricular activity for Riley was as a member of the Zeta Chapter of Alpha Gamma Delta Sorority and she remained an active alumna (26).

Nannie Louise Nease (10/29/1881-6/22/1945) entered Ohio University in the Fall term 1899. She was from Point Pleasant, Mason County, West Virginia, roughly 40 miles from Athens. Nease appears to have been the only daughter of Rebecca "Bettie" Jane Somerville and Hosiah Green Nease, a proprietor of a grocery and dry goods store. The only known extracurricular activity for Nease was pledging Pi Beta Phi fraternity for women (27). Nease's future husband, Horace McCord, also attended Ohio University for two years having matriculated in Fall 1898 and served as manager of the baseball team (28).

The Ph.B. was conferred to Riley and Nease on June 18, 1903. In total 16 bachelor's degrees were conferred in 1903, five with the A.B., one with the B.S., and ten with the Ph.B.

Ethyl Riley Thesis

Riley's eleven-page thesis entitled "The Nitro-Derivatives of the Hydrocarbons" (29) was submitted June 16, 1903, and received a "Satisfactory" from Professor Bentley. Spelling errors were frequent. Several researchers were named but only two literature references were

cited. The introductory page is shown in Figure 1.

Riley first discussed the general substitution reactions of saturated hydrocarbons with nitric acid and of aromatic hydrocarbons with a mixture of concentrated nitric acid and sulfuric acids at low temperatures, except for aromatic amines which produce a mixture of nitroanilines. Riley then described several nitration reactions.

The general preparation of nitrobenzoic acid from a mixture of benzoic acid, saltpeter (potassium nitrate) and concentrated sulfuric acid was presented. A specific step-by-step formation and isolation of nitrobenzene and dinitrobenzene from nitric acid and sulfuric acid followed. She did not specify which isomer of dinitrobenzene was obtained and wrote the wrong formula— $(C_6H_4NO_2)_2$ instead $C_6H_4(NO_2)_2$.

The conversion of aniline through the diazo stage to form phenol by reaction in sulfuric acid and sodium nitrite was provided. A procedure for the preparation of nitrophenols was also described, with both *o*-nitrophenol and *p*-nitrophenol produced, but while an excellent yield was claimed, there was no characterization of the products obtained.

The final experiment described converting aniline in a solution of diluted nitric acid and sodium nitrate which was poured into a $CuSO_4$ solution producing nitrobenzene. Typically, the experimental characterizations of products were based on material color and melting point determinations, or distillation temperature, color and odors of liquids/oils obtained, such as nitrobenzene.

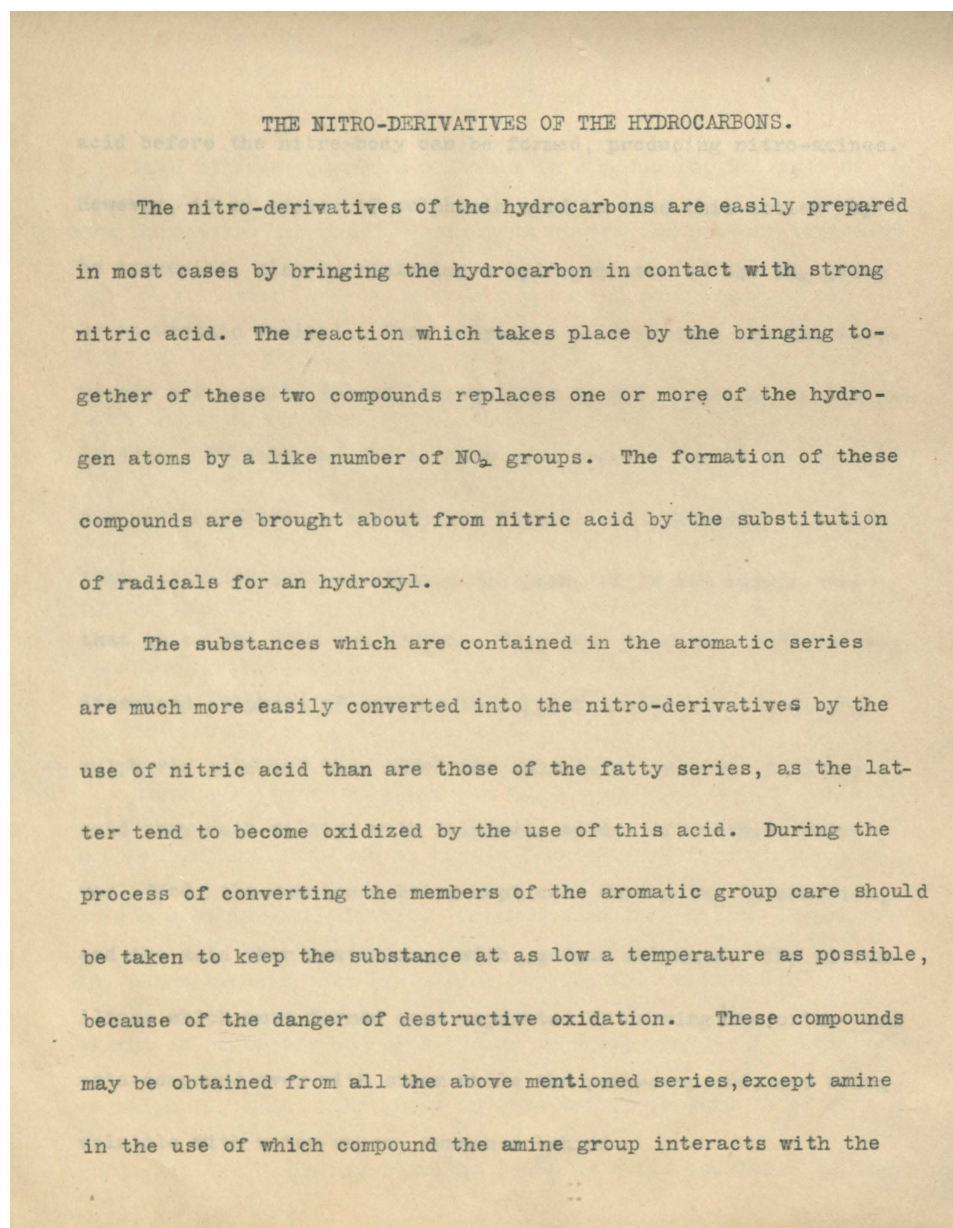


Figure 1. Introductory page to the Ohio University Ph.B. Thesis submitted by Ethel Riley in June 1903 titled *The Nitro-Derivatives of the Hydrocarbons*.

Nannie L. Nease Thesis

Nease's twelve-page thesis was entitled "The Bromo-Derivatives of the Hydrocarbons" (30). It shows no date of submission nor any grade notation. The copy contains several hand-written corrections throughout the text. As with Riley, several researchers were mentioned, but only one literature reference was cited. The introductory page is shown in Figure 2.

Nease described the bromination of ethane, ethylene, and aniline using liquid bromine. Bromine's dry volatil-

ity and uses with solvents (e.g., ether, chloroform, hydrochloric acid, and carbon disulfide and less so with alcohol or potassium bromide solution) and with "carriers" (e.g., iodine, iron, ferric bromide, ferric chloride, and phosphorus) were discussed. First, ethyl bromide was prepared from the reaction of ethanol with bromine in the presence of red phosphorus. After product formation, it was purified by shaking with NaOH to remove the HBr and redistilled. The boiling point of 40 °C was reported which compared with a literature value of 38.8 °C. The reaction process involving the formation of PBr_3 was discussed. Properties and other reactions of other halogenated hydrocarbons (ethyl chloride and ethyl iodide) and differences between them were given.

Next, Nease discussed some differences between saturated and unsaturated hydrocarbons. The second reaction performed was a two-step preparation of ethylene bromide. First ethanol was heated with an excess of concentrated sulfuric acid. The gases produced were passed through a caustic soda solution to remove the SO_2 produced and then through an aqueous solution of bromine to form the ethylene bromide. The resulting mixture was neutralized with caustic soda. After separation of the aqueous and oil layers, calcium chloride was added to the organic layer before distillation. The boiling point of the ethylene bromide was reported as

THE BROMO-DERIVATIVES OF THE HYDROCARBONS.

Most hydrocarbons are very susceptible to the influence of the halogens, and it is possible to form a large number of derivatives by replacing the hydrogen of the hydrocarbon by the halogen radical, it always being the rule that the derivatives contain the same number of halogen atoms in the place of the same number of hydrogen atoms. The halogen bears the same relation to the carbon atoms that the replaced hydrogen did. Products formed in this way are known as the substitution products, and the groups formed by the halogens are known as the halogen substitution products. There are also those products formed by the action of nitric acid, the nitro-substitution products, and those formed by the action of sulphuric acid, or the sulphonic acids.

The substitution products to be treated of here are the bromo-substitution products of ethane, which has a formula of C_2H_6 . In most cases bromination is effected by the use

Figure 2. Introductory page to the Ohio University Ph.B. Thesis submitted by Nannie L. Nease in June 1903 titled *The Bromo-Derivatives of the Hydrocarbons*.

127 °C. Neither the name of the compound as ethylene dibromide nor any formula were given.

After some background discussion about aniline and its natural sources and properties, the final compound prepared was "aniline bromide or tri-brom aniline."

The aniline was mixed with hydrochloric acid and then bromine was passed from a cylinder into the solution resulting in the initial formation of a white precipitate that became a deep yellow. After filtering, washing, and drying the boiling [*sic*, [melting] point was found to be 121 °C as compared to literature values between 118 and 120 °C.

Bound copies of both theses are held in the Special Collections of the Libraries of Ohio University. Originally, the Dewey catalogue entries were 378.771 0370ri and 378.771 0370ne, though both were re-catalogued in 2008 as Thesis BA 1903 RILE and Thesis BA 1903 NEAS instead of the Ph.B. degree.

Post-Graduation Lives of Riley and Nease

After graduation in 1903, Riley began a high school teaching career in Salt Lake City, remaining until 1917, when she moved to Washington, DC, and initially worked at the War Industry Board as a stenographer. After her government service she spent twenty-five years as a teacher in the business practice department of what was known as the Business High School which became Roosevelt High School. Besides her sorority alumna involvement, Riley was a member of the American Association of University Women and the New York Avenue Presbyterian Church. She also served as advisor to the Girl Reserves at Roosevelt. She died suddenly at her home in Washington on Sunday, November 5, 1944. She was buried in the Carthage Cemetery in Coolville, Athens County, Ohio (31).

Nease married Horace Minor McCord (4/3/1880-8/31/1943), a native of Pickaway County, Ohio, on October 22, 1906, in Point Pleasant, West Virginia. He was employed by the National Cash Register Company in Dayton, Ohio, at that time. As previously noted, McCord had attended Ohio University for two years, but did not graduate. He was the fourth child in a family of three boys and two girls. There was one daughter, Elizabeth "Betty" Lee McCord born on August 11, 1907, to Horace and Nannie McCord. In the 1920s, the McCords had moved to Columbus, Ohio. Horace worked as a salesman with several firms and served as the president of the McCord-Harris Company with James W. Harris as vice president. The McCord-Harris Company was a distributor of the Chandler Six and Cleveland Six motor cars before the brands were discontinued in the late 1920s (32, 33). Also, he was a member of the Ferris-McCord Tire Company. Horace died in Marion, Ohio, on August 31, 1943, after a brief serious illness (34). At the time of

his death the McCords were living in Grove City, Ohio. Their daughter had graduated from Ohio State University in Columbus, Ohio, and became a journalist. She was married to William Smith Cunningham on August 9, 1930. After Horace's death, Nan lived with her daughter and son-in-law in Los Angeles, California; she died there on June 22, 1945 (35). Both Nan Nease McCord and Horace McCord were buried in the Lone Oak Cemetery, in Point Pleasant, West Virginia. Betty (McCord) Cunningham had no children; she died in 1990.

Significance

This section presents some information about the state of higher education, particularly in chemistry and for women, among other colleges and universities in the US, particularly in Ohio. It is intended to serve as a backdrop for comparison of the details presented above about Ohio University and its first two women chemistry graduates.

At the start of the nineteenth century, only six American universities (Columbia, Dartmouth, Harvard, Pennsylvania, Princeton, and William and Mary) offered separate courses in chemistry (36). As noted earlier, the classical curriculum and natural science study were replaced in the last quarter of the nineteenth century with more disciplinary focus. Further, the emergence of graduate programs began to provide designation beyond simply earning a B.A. or B.S. While women increasingly were being admitted to colleges and universities, few were in the sciences, especially chemistry. Often, they were unable to find employment or were refused "men's jobs," and a separate labor market emerged in the sciences for women, even if they had earned a Ph. D. "It was assumed that most women were seeking personal fulfillment and were planning to become better wives and mothers" (37).

There were a few notable women to earn academic degrees in chemistry in the last few decades of the nineteenth century. Ellen Henrietta (Swallow) Richards (1842-1911) was the first woman in America accepted to any school of science and technology, and the first American woman to obtain a degree in chemistry, which she earned from Vassar College in 1870. After failing to find work as an industrial chemist she enrolled at the Massachusetts Institute of Technology (MIT) as the first woman admitted there. She graduated in 1873 with the B. A. and with an M.A. from Vassar in the same year. She completed her Ph.D. at MIT in 1886 and later became its first women professor, but initially in unpaid programs especially created for women (38, 39).

Mary Engle Pennington (1872-1952) entered the University of Pennsylvania in 1890 and completed the requirements for a B.S. degree in chemistry in 1892. However, since the University of Pennsylvania did not grant degrees to women at this time, she was given a certificate of proficiency instead of a degree. Pennington received her Ph.D. under Edgar Fahs Smith from the University of Pennsylvania in 1895 (40, 41). As will be seen below, these were the most prominent American women chemists educated before the turn of the twentieth century.

Besides Ohio University, several institutions of higher education opened in Ohio in the nineteenth century. Miami University in Oxford had been chartered in 1809 and opened in 1824. This was followed by the present University of Cincinnati which was established in 1819. Private institutions emerged at Kenyon College in Gambier in 1824, Western Reserve College (now Case Western Reserve University) in Cleveland in 1826 and in the 1830s Capital University in Columbus, Denison University in Granville, Xavier University in Cincinnati, Oberlin College, Marietta College, and Muskingum University in New Concord all opened. Wilberforce University was founded in 1856 to educate African American students, and the co-located public Central State University opened in 1887. Ohio State University was founded in Columbus in 1870 as the Ohio Agricultural and Mechanical College. By the turn of the twentieth century, over 40 colleges and universities had opened in Ohio; 20% were public.

Women began to enroll in Ohio colleges before long, although not in great numbers. Oberlin is the oldest coeducational college in the US having admitted four women in 1837; three of whom graduated (42). Mary Jane Patterson (1840-1894) graduated in 1862, the first Black woman to earn a B.A. degree and became a pioneer in Black education (43).

At Ohio State University the first woman graduate was Mary Franc Morrison (?-1930). She studied microscopic chemistry and received the B.A. degree in 1879; upon which she taught natural science in Cincinnati before she married in 1881 (44, 45). At Ohio State University, there is no mention of women students registered in the chemistry courses in the first year in 1873, but an 1888 chemistry class photo shows at least eight women in a class of approximately 50 students (46). In 1897, a four-year course in chemistry, leading to the degree of Bachelor of Science in Chemistry was adopted. Of the first 10 students to earn the degree through 1901, none were women (47). Ohio State University began award-

ing the doctorate in 1891 and had awarded only one to a woman before 1900 (48).

At Miami, the Oxford Female College opened in 1856 and offered lectures on botany, chemistry, and natural philosophy in Miami University; the first baccalaureate degrees were conferred in 1886. In 1891 Miami admitted seventeen women students, and in 1900 three of sixteen women were awarded bachelor's degrees (49, 50).

In 1902-1903, nearly 30,000 bachelor's degrees were conferred in the US, with just over 6,000 awarded to women (51).

In the 1906 edition of *American Men of Science*, of the 1000 "starred" scientists (leaders in research in the science) 175 were chemists; but only 19 of the 1000 were women and only one was a chemist; it was Richards. By the time of the second edition in 1910 with an additional 250 starred scientists of which 55 were chemists, only six of the 250 added were women, and only one was a chemist; it was Pennington (52). Eighteen Ohio colleges and universities had produced starred male scientists by the 1940s. The leading institutions in Ohio for production of starred chemists by 1910 were Cincinnati with one, Miami with one, Oberlin with two, Ohio State with seven, and Wooster with one; none were women (53). The baccalaureate origins of women chemists before 1920 showed a total of 35 across 108 institutions, but none had come from any Ohio institution, including Oberlin and Ohio State and only Ohio State had employed women scientists (54).

The fact that Ethel Riley and Nannie Nease each wrote a chemistry-related thesis for their Ph. B. is the only way we know they were the "first" women at Ohio University to have earned a chemistry-related degree since no official designation existed in that period. The fact that both followed traditional career paths for women was not surprising either, even expected, for the time.

Conclusion and Epilogue

In the first 100 years of Ohio University, only a handful of students had graduated with a bachelor's degree with an affiliation in chemistry. Two of these were women, Ethel Eleanor Riley and Nannie Louise Nease, who earned the Ph.B. in 1903 writing theses on derivatives of hydrocarbons under the guidance of a Harvard University educated organic chemistry faculty member, William Bentley. Riley went on to a career as a high school business teacher; Nease married shortly after her graduation, bore a daughter, and supported the work of

her husband as a salesman. While several chemistry-related bachelor's degrees would continue to be earned by male students, Riley and Nease stood alone with their chemistry-related Ph.B. theses at Ohio University for over a quarter century until Harriet Maxine Paine earned the B.S.Ed., on June 9, 1930; followed by the A.B. degree in chemistry earned by Spanish-born Abelina Suarez on June 8, 1931, both of whom went on to long careers as high school science teachers.

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EDA BACHMAN WALDEN: WHAT WERE HER CONTRIBUTIONS?

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Abstract

One of the first women to graduate with an undergraduate chemistry degree from Butler University was Eda (Bachman) Walden. While her career as a scientist was brief, there is evidence that she was a talented researcher who may have contributed to the production of insulin. Her path as a researcher and scientist are presented here.

Background

In the late 1800s and early 1900s, few women earned undergraduate degrees in the sciences, especially chemistry (1). In addition, smaller academic institutions awarded general BS or BA degrees, rather than stand-alone degrees in disciplinary subject areas. The first documented woman in the United States to earn an undergraduate degree in chemistry was Ellen Swallow Richards from Vassar in 1870, and she went on to teach at MIT (2). Richards was directly responsible for at least eight more women publishing research work and five of them earning undergraduate degrees from MIT (3). Many of the women listed in Creese's text either earned generalized BS degrees, degrees in allied fields (pharmacy, biology), or studied chemistry in Europe.

Indiana schools founded before the year 1900 also followed these national norms. State-sponsored institutions, like science-oriented Purdue University (founded in 1869) awarded its first chemistry degrees in 1875 (4). Purdue has the distinction of first female undergraduate

chemistry major in the state of Indiana, Martha Doan, in 1891 (5). The flagship state school, Indiana University (founded in 1820), did not award chemistry degrees until 1890 (6), and there are no records of the first woman to receive one. Other state-sponsored schools did not award chemistry degrees until recently, like Indiana State University (founded in 1865), which was the state teachers' college, and Vincennes University (founded in 1801), which was rechartered in 1889 as a two-year institution. Large private institutions such as the University of Notre Dame (founded in 1842) established the College of Science in 1865 with chemistry degrees awarded two years later (7), but it did not become co-educational until 1972, which finally allowed women the opportunity to earn science degrees (8).

Several smaller Indiana schools may also have had early women science graduates as many of them were founded as coeducational institutions. DePauw University (founded in 1837) became coeducational in 1867, and defined the courses required to earn a chemistry degree in 1896 (9). Earlham College (founded in 1847) was the second school in Indiana to be founded as coeducational (10). Franklin College (founded in 1834) was the second school in the country, and the first in Indiana, to be founded as a coeducational institution behind Oberlin College, Ohio (founded in 1833) (11). Huntington University (founded in 1897), was also coeducational, and it highlighted applied sciences in its early curriculum (12). St. Mary's College (founded in 1844) and St. Mary-of-the-Woods College (founded in 1840) were

both all-women schools, but early records indicate that physical sciences were not part of the curriculum (13, 14). Taylor University (founded in 1846) had a medical school for a time. Alice Hamilton, the first female faculty member at Harvard University, took courses at Taylor's medical school, but did not graduate from there (15). The University of Evansville (founded in 1854) was the fifth coeducational college in the US (16). Valparaiso University (founded in 1859), also founded as a coeducational institution, was well regarded for engineering and medicine (17). While these schools clearly had women in their programs, there is not substantive evidence for women graduating from their programs with science degrees in the late 1800s to early 1900s.

Other Indiana institutions founded before 1900 were unlikely to have had female chemistry graduates during this time period. Some of these schools identified as teachers' colleges (Marian University, Trine University, and the University of St. Francis). One school identified as a bible college (Manchester University). One school presently has sciences as minors (Oakland City University). One identified as an agricultural institution (Goshen College). Three institutions were all-male at that time: Hanover College, Wabash College, and Rose-Hulman Institute of Technology. In addition, Rose-Hulman offered a degree in chemical engineering, but did not award its first undergraduate chemistry degree until 1958 (18).

Butler University (founded in 1855) was the third school in Indiana to be founded as a coeducational institution. Butler began to see declarations of majors on academic transcripts starting in 1910, rather than a BA through the "general course," the "general course 2" (which was more science heavy), or the "premed course" (which included more biology) (19). Butler University's first official chemistry major, Newton Clarence Browder, graduated in 1916, though most of his classmates were awarded the general BA degree (20).

Any student that entered Butler after June 15, 1917, was required to declare an academic major (21). Chemistry majors, both men and women, appeared regularly amongst the graduating seniors from this point forward. Eda Bachman was the first woman to graduate from Butler with a BA in chemistry in 1918 (20).

Early Life

Eda Bachman was born on January 3, 1897, in Indianapolis, Indiana, to German immigrant Valentine Bachman and Carolina "Lina" von Königslöw of Cleveland,

Ohio. Valentine was a miller by trade and by 1910 he owned a residence in Woodruff Place (22), an Indianapolis neighborhood of Victorian homes (23). Eda was the youngest of four daughters (Elsa, Irma, and Charlotte). The Bachmans engaged in local social events, with Eda and Charlotte participating as milkmaid dancers in May Day festivities (24). Elsa had a degree in jewelry making from Pratt Institute (25). Irma, Charlotte, and Eda all attended Butler College, which became Butler University. Irma and Charlotte went on to become teachers (26). Eda enrolled at Butler in the fall of 1914 and pledged the Kappa Alpha Theta sorority (Figure 1) (27). In 1918, she graduated with highest honors, and was the first woman to earn a degree in chemistry from Butler University.



Figure 1. Eda Bachman's Pledge Photo (courtesy of the Kappa Alpha Theta archives).

Worklife

Soon after graduation, in July of 1918, Eda was hired by Indianapolis-based Eli Lilly & Co. as a research chemist (Figure 2). This hire date indicates that she would have been the first female research scientist to be hired by Lilly. This was not unique to the chemical industry as many companies were hiring women scientists in 1917 and 1918 (28). Eda worked under the prominent research scientist, Dr. George Henry Alexander Clowes (29). Clowes was the first Research Director at Eli Lilly & Co. Her employment card also indicates that she was "separated" from Lilly in December 1921. She married coworker and fellow chemist, George Walden, on January 11, 1922. It was common at that time (and later) for women to stay at home once they were married.

Bachman, Eda		
<u>D.O.B.</u>	<u>Retirement</u>	<u>Obituary</u>
7-1-18		
Position:	scien. chem.	
Comments:	sep. 12-24-21, XIR/j	

Figure 2. Eda Bachman's employment card (courtesy of Eli Lilly & Co. archives).

In addition to his employment and research at Lilly, Clowes had an arrangement that he would conduct research at Woods Hole (Massachusetts), the scientific center now known as the Woods Hole Oceanographic Institution, during the summer months. Several members of his Lilly research team joined him during the summer, including Eda for the summers of 1920, 1921, 1922, 1924, and 1925 (30). During this time, she and Clowes published research on sea urchins (31). Notably, Eda is listed as either a chemist or research chemist with Eli Lilly & Co. for the summers of 1922, 1924, and 1925—after her separation from the company.



Figure 3. Eda at work (courtesy of the Walden family).

Insulin

The discovery, purification, and the US distribution of insulin by Eli Lilly & Co. has been well documented (32-35). There is no doubt that Clowes and George Walden were the chemistry team that worked with the Canadian team to purify insulin. What is not clear is the role, if any, that Eda had in this process with Walden and Clowes.

Arguments for Intimate Involvement of Eda with Insulin

There is the possibility that Eda was involved as a research scientist on the insulin project, under her married name, and the record has been lost. Her husband was appointed to work on this project in the spring of 1922, after they were married (32-35). Several sources point to her being a member of the scientific team involved in the research effort.

Among the principal laboratory technicians at Lilly who were assigned to the project was a research chemist, George B. Walden, and his wife, Eda Bachman Walden, who was also a chemist (36).

George Walden headed insulin research at Lilly, and Harley W. Rhodehamel, Jasper P. Scott, and Walden's wife, Eda Bachman, all chemists, assisted in the project (37).

The team at Eli Lilly began its work immediately, led by George Walden, Harley Rhodehamel and Jasper P. Scott, as well as Eda Bachman, a chemist who would later marry Walden... Walden's research with Bachman also included a basic science program focused on determining the isoelectric points of materials in several of Lilly's products. (The isoelectric point was a well-known chemical principle, defined by the pH of a medium at which a protein carries no net charge and thus will not migrate in an electric field. Proteins precipitate—fall out of solution—most readily at their isoelectric points, a property that can be utilized to separate mixtures of proteins or amino acids) (38).

Lilly's husband-and-wife team, George B. and Eda Bachman Walden, both chemists, solved this problem by adding a special isoelectric precipitation step that ensured a potent product of standard purity (39).

Several of these come from the same source material, Khan in particular. However, there are records from McCormick, who was the Lilly historian, and a letter from J. K. Lilly to Clowes that seem to corroborate this involvement by Eda (36). Several other references do not point to source material, but likely could have been propagated from already referenced items (38, 39).

Arguments for Ancillary Involvement of Eda with Insulin

Annual reports from the archives at Woods Hole makes it clear that Eda was a researcher there summers from 1920 through 1925 (with the exception of 1923). It is also clear that the use of the isoelectric point for precipitation of proteins came from the synergy of work between Clowes, researchers at Woods Hole, and the team at Lilly (40):

Walden decided to make use of the isoelectric protein precipitation method, which he had learned while working at Woods Hole in the summer of 1921. A colleague, Jacques Loeb, had shown him the relative positive and negative charges of a particular protein depend on the pH of the solution... Walden had successfully applied this principle to a series of Lilly protein products.

However, in 1921, there is no record of Walden performing research at Woods Hole. Jacques Loeb is noted on the annual report (41), as well as Clowes, Eda, Irvine H. Page, Homer W. Smith, and Carlotta G. Smith from Eli Lilly & Co. Walden is listed as a researcher in 1924 and 1925 (42). It is possible that Walden came for a short period in the summer of 1922 (Loeb was present this summer as well), which is likely as Eda and Walden were newlyweds, but not the entire summer. As the contract to make insulin was awarded in May, it is highly likely that Walden, as head chemist, was dedicating most of his summer supervising the work in Indianapolis. It is also possible that Eda, or another member of the Lilly team, had worked on this technique with or without Walden in previous years at Woods Hole. This is supported by the following quotes:

Fortuitously, Lilly chemists George Walden and his future wife Eda Bachman were conducting independent research on proteins at Woods Hole. The Walden team's basic science program on isoelectric precipitation involved new applications of a well-known principle (43).

It should be emphasized that Walden's isoelectric precipitation technique emerged from a basic science program started by Clowes in Woods Hole that had nothing to do with insulin (44).

The meaning of the listings of the Lilly team in the Woods Hole annual reports are not clear. In 1920, Eda is listed as a "research chemist" along with Lucille G. Keith. In 1921, Eda is again a "research chemist," while Irvine Page is a "chemist," and Homer and Carlotta Smith are simply affiliated with Lilly without titles. Mabel T. Studebaker was not listed as a chemist in 1922 (Eda and Page were). In 1924, Eda and Walden were listed as a "research chemists," while Page was labeled "research" and Studebaker was labeled "chemist." In 1925, Page is a "research worker," Walden is a "research chemist," and Eda is a "chemist." It is not clear if Eda was granted the same research privileges at Woods Hole as a non-employed chemist, or she continued to work at Lilly under her married name and there are no records of this, even after an extensive search, in the Lilly archive.

Rather than a scientific role, Eda could also have served as an archivist of the insulin data (45):

Information about early insulin production at Lilly was obtained from a six-volume series of laboratory data entitled "Insulin Research" for the years 1922 to 1925. The entries, mostly recorded by Mrs. George B. Walden, who was an employee at the time, noted the date of each lot, the numbers assigned to it, the extraction procedure, and the assay results. The volumes are in the Lilly Archives.

It was common for women's roles in the chemical industry to change over time from researchers during World War I to "'chemical librarians,' 'chemical secretaries,' bibliographers, and abstractors" (46). In this role, she may not have been an official employee of Lilly, or she may have been classified as secretarial.

Arguments Against Eda's Involvement with Insulin

Insulin production by Eli Lilly & Co. did not begin until the agreement was signed with the Canadian researchers in the late spring of 1922 (32-35). Her husband, George Walden, who was hired in 1917, was the chemist in charge of the project working directly with Clowes. This was after Eda's documented separation.

Several of the documented histories about the production of insulin did not include Eda on the team of researchers. Cooper and Ainsburg list Jasper P. Scott and Harley W. Rhodehamel along with Walden, and there is no mention of Eda on any of the pages referencing Walden (47). Rosenfield lists no team at all, but does include a timeline of critical development in the insulin project between October and December of 1922 (48). Bliss states that "A team of chemists, headed by George Walden, devoted their full time to the insulin work" (49), but there is no mention of Eda. In the biography of his grandfather, Alexander W. Clowes does not include Eda on the team either. "...The Lilly team comprising George Walden, Harley Rhodehamel, and Jasper P. Scott..." (50) are the only ones included. Of these three scientists, only Walden could have spent time at Woods Hole, where the critical method of isoelectric precipitation was shared. There is no record of Scott or Rhodehamel traveling to Woods Hole.

It would be easy to assume that Eda had no part in the production and/or purification of insulin. Why would one think she would have been included? Employment records show that she was separated. Women were often viewed as assistants, but not as equal scientists (28). Several of the accepted authorities on the discovery and

production of insulin do not mention any contribution by her.

Conclusion

Despite the arguments against her direct involvement, there seems to be some consensus in the literature that Eda Walden Bachman had some role in the purification and production of insulin by Lilly. Exactly what that role was may be lost. It could easily be a case of a woman researcher overshadowed by her more famous, more accomplished spouse who went on to become the vice president for Biochemical Manufacturing.

The Waldens settled in a farm home on the South side of Indianapolis and raised their two sons George Jr. (1923-2014) and Philip (1929-2016). George Jr. was a mechanical engineer (51). Philip was a broadcast engineer at Purdue University (52). Walden retired from Lilly in 1960 (51). He died in August of 1982, and Eda died in January of 1988 (53).

Even though her career as a working scientist was brief (1918-1925), she contributed a significant amount to the field during this time. Apportioning credit for individual scientists' contributions to large scientific efforts like insulin are challenging due to the lack of surviving documentation and differing perspectives of researchers on the project, as evidenced by the multiple investigations on this topic (29, 32-38). Compounding this challenge, the role(s) of women in research was often underrecognized (54). Regardless of Eda's role in insulin research, she has several incontrovertible credentials in science. She was the first woman to graduate with a chemistry degree from Butler University, she was the first documented female research chemist at Eli Lilly & Co., she was a multi-year visiting researcher at Woods Hole, and she was a coauthor on a publication with G. H. A. Clowes, a famous scientist of his time. On these merits alone, she should be lauded as an extraordinary and impactful female chemist.

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SIR WILLIAM RAMSAY: PIONEERING ADVOCATE FOR WOMAN CHEMISTS

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During the 19th and the first part of the 20th centuries, women required a male “benefactor” for access to the world of chemistry. We have shown previously that Frederick Gowland Hopkins enabled women access to the world of British biochemistry from about 1900 until 1940 (1). Though there was much opposition to women, there were other facilitators, one of whom was William Ramsay.

Ramsay is rightly remembered for his contributions to inorganic chemistry, particularly the discovery of the noble gases (2). However, long overlooked has been his advocacy and support for women chemists. In a recent publication on Ramsay’s life and work (3), a list was provided of students who he supervised and who subsequently became famous in their own right. These were, of course, all males. In those times, women never had the opportunity to advance academically. Thus, excluded from any mention, were his women research students.

Not only did Ramsay take on women students, but they were given equal authorship on publications, or, most frequently, permitted to publish under their name alone. It was the fact that Ramsay’s name was lacking from most of the women’s publications that probably led to his women-supportive role being overlooked.

Ramsay and the Admission of Women to the Chemical Society

Before providing a compilation of some of Ramsay’s women students and their chemistry contributions, we begin by looking at his promotion of the admission of women to the Chemical Society. The Chemical Society had been founded in 1841, but it was not until 1880 that the question was raised of the admission of women (4).

In the initial discussion that year, legal opinion was given that, under the Charter of the Society, women were admissible as Fellows. The Oxford chemist, Augustus G. Vernon Harcourt proposed a motion to clarify the bye-laws, so that any reference to the masculine gender should be assumed to include the feminine gender (5). The motion was rejected as “not expedient at this time.”

Taking up the fight a second time, William Ramsay put forward a similar proposal in 1888, but after lengthy discussion, this motion was also withdrawn, the Secretary noting (6):

... the general feeling being that although there was no objection in principle to the admission of women as Fellows, the case in their favour was not entirely established.

In 1888, the admission of women had been a theoretical question. However, in 1892, four years later, a woman chemist applied for Fellowship in the Society.

The long controversy started innocuously, as the Minutes of the Council Meeting describes (7):

The Secretary having read a letter from Prof. Hartley suggesting the election of a lady as Associate, Prof. Ramsay gave notice that he would move that women be admitted Fellows of the Society."

The motion, proposed by Ramsay and seconded by William Tilden, came the following January (8). With substantial opposition, the motion was defeated, and it was not until 1920, that the first women were admitted to the Chemical Society.

Katherine Williams

In 1880, Ramsay accepted an appointment as Professor at University College, Bristol. It was at Bristol that he took on his first woman student: Katherine Isabella Williams (9). Williams was born in 1848 at Llanwelly, Monmouthshire, Wales, daughter of Thomas Williams, Dean of Llandaff, and Elizabeth Davies. She was educated at King Edward VI High School for Girls, Birmingham and in 1877 at the age of twenty-nine, became a research student at University College, Bristol.

In the late 1880s, Williams commenced a collaboration with Ramsay. Her first research was on the solubility of oxygen in water (10), then she worked on the existence of a possible allotrope of nitrogen (11). Morris Travers, in his account of Ramsay's life and work, mentioned twice that Ramsay suggested Williams repeat the Cavendish experiment on air (12):

It is said that he [Ramsay] suggested that she should repeat the Cavendish experiment on air, but she chose something easier, the determination of the oxygen dissolved in water. Later, when he and Miss K. Williams, at Bristol, were investigating an alleged allotropic form of nitrogen, he says that he suggested that she should repeat the Cavendish experiment; but the matter went no further.

It was the later repetition of Cavendish's experiment by others that resulted in the discovery of the noble gases. Had she pursued the topic, it would have probably resulted in considerable recognition of her research.

Williams then embarked upon her own research programme in food analysis. It was Ramsay who had suggested that she research the chemistry of foods, as William Tilden noted in his biography of Ramsay (13):

At Bristol in the early days of the College there were but few advanced students capable of taking part in research. Among these Miss K. I. Williams, whose death took place in January 1917, deserves to be men-

tioned. Ramsay suggested to her an investigation into the composition of various foodstuffs, cooked and uncooked, and this enquiry occupied her continued attention till the close of her life thirty-five years later.

Working as an unpaid independent research student over a period of 24 years, Williams authored 10 papers on the chemistry of food (14). As a result of her food chemistry research, Williams was awarded a B.Sc. (Bristol) by research in 1910.

In 1909, Williams was one of the 24 women members of the 7th International Chemical Congress in London (15). She was in Switzerland when the First World War commenced, and according to an obituarist (16), the "anxiety and actual hardships she suffered before being able to return to England told severely on her constitution." Williams resided for much of her life with her elder sister, Elizabeth, in Clifton, Bristol, where she died in March 1917.

Unfortunately, the full account of her research on food chemistry was never published, as the following comment in the obituary described (16):

Sir William Ramsay and others had induced her to write a popular account of her work, and Sir William had promised to write a preface. This was completed about a year ago, but he had passed away before the promise could be carried out, and Miss Williams died before the work had gone to the publishers.

Emily Aston

It was in 1887 that Ramsay accepted an appointment as Chair of Chemistry at University College, London (UCL). Here he took on his subsequent women research students, the first being Emily Alicia Aston, the first woman chemistry researcher at UCL. Aston was born in Paddington in 1866 to Joseph Keech Aston, Barrister, and Sarah Alice Eccles (17). She commenced her university education at the all-women Bedford College, London University, to study chemistry. It was while at Bedford that Aston undertook her first research work: the investigation of mixed-metal sulfates under the direction of the Chair of the Chemistry Department, Spencer Pickering (18).

Aston transferred to UCL in 1885, completing a B.Sc. in chemistry and geology in 1889. She remained at UCL after graduation, taking additional courses, particularly analytical chemistry. However, most of Aston's time was spent undertaking research. Her first publication from UCL, unsuccessfully attempting to repeat Wöhler's claimed synthesis of a mixed oxide of silver and lead,

was under her name alone, though she noted that the topic had been suggested to her by Ramsay (19).

Upon joining Ramsay's research group, she co-authored five publications in a variety of areas in physical chemistry (20). In Travers's biography of Ramsay, he made reference to Aston's research (21):

Ramsay carried out further experimental investigations in the same direction with John Shields and with Miss Emily Aston, and made attempts to deduce from the results the degree of complexity of associating liquids.

Aston's research versatility and productivity was remarkable. In addition to her research with Ramsay, she co-authored publications with other chemistry professors at UCL: a physical chemistry paper with James Walker (22) and an organic chemistry paper with J. Norman Collie (23).

Aston also performed chemical analyses with UCL geologist, Thomas George Bonney. She analyzed water samples sent by explorers in Sudan (24), while UCL geology research student, Catherine Raisin, undertook corresponding mineral classifications (25). Aston also analyzed specimens of Alpine minerals, several of which were supplied by Ramsay from his hiking expeditions (26).

One of Aston's published research notes was on the analysis of zinc oxide by converting it quantitatively to zinc sulfide (27). This paper is particularly intriguing as it was not co-authored with a university professor, but with a woman chemistry student, Lucy Newton. Newton was born in 1867 at Scarborough, Yorkshire, her father being Edward Hotham Newton, Bank Director and Brewer, and her mother, Elizabeth Blundus Taylor (28).

Newton first attended Nottingham University College, being awarded a Cambridge Certificate together with a College Certificate for Theoretical Chemistry and Qualitative Analysis in 1884 (29). In 1886, she entered Newnham College, Cambridge, completing the Natural Science Tripos in 1889. Newton stayed on at Newnham for an additional year, and then held the position of Assistant Demonstrator in the Newnham chemistry laboratory from 1891 to 1893. At some subsequent date, she moved to UCL to undertake the analytical chemistry research with Aston which was published in 1897. Newton died in 1903 in Malta, age 35. No information could be found on her later years.

During the late 1890s, Aston spent some time at the Sorbonne in Paris where she worked with Paul Dutoit

on electrolytic conductivity and molecular association resulting in two publications (30); then she undertook research with Philippe Auguste Guye at the University of Geneva, Switzerland, on optical rotation, co-authoring four publications (31).

Aston then returned to England, resuming research with Ramsay, resulting in one publication (32). This was the last record of her. In all, Aston co-authored or sole-authored 18 research papers, certainly the most of any woman chemist of the period. According to census information of 1901 and 1911, her occupation was noted as "private means." Aston died in 1948 at Uckfield, Sussex.

Ida Homfray

Ida Frances Homfray was another woman researcher with Ramsay. Born in 1869 at Newcastle-under-Lyme, Staffordshire, she was the daughter of George Homfray, Engineer, Coal and Iron Mines, and Marion Sarah Block (33). Unfortunately, little can be found on Homfray's life. We do know that she worked with Ramsay between about 1900 and 1910, only her first publication being co-authored with Ramsay (34). Another publication, like some of Aston's, involved collaboration with Guye at the University of Geneva (35). Homfray was sole author on three papers relating to liquid surface properties (36). During her time at UCL, she obtained a B.Sc. by research in 1905, followed by a D.Sc. in 1910. Homfray's later research focussed on the absorption of gases by charcoal, studies that were very relevant to the gas masks of the First World War (37). No later records of her could be found, except her death in Hampstead in 1948.

Some Other Women Researchers with Ramsay

Each of Williams, Aston, and Homfray spent a significant period undertaking research with Ramsay. In addition, there were several women researchers whose length of time working with him was briefer. Here we will mention three of them.

Katherine (Kate) Alice Burke entered UCL in 1899, working in Ramsay's laboratory under the direction of Frederick Donnan (38). Besides undertaking research with Donnan and with E. C. C. Baly, she acted as Private Research Assistant to Ramsay. One of Burke's tasks was to translate into English a book by the Danish chemist, Julius Thomsen, on systematic research in thermochemistry.

Dorothy Blanche Louisa Marshall began her university education at the all-women Bedford College, London University in 1886 (39). From there, she transferred to UCL, studying chemistry, physics, and electrical technology and graduating with a B.Sc. in 1891. Staying at UCL as a post-graduate researcher until 1894, Marshall studied heats of vaporization of liquids, her work resulting in three lengthy publications, one of which was co-authored with Ramsay (40).

Clare de Brereton Evans began her research career later in life. Evans had been appointed Lecturer at the London School of Medicine for Women (LSMW) in 1897 (41). She combined her LSMW teaching with part-time research at near-by UCL under Ramsay. Ramsay had many of his research group searching for new chemical elements. He was convinced that the thorium-containing mineral, thorianite, a sample of which he had obtained from Ceylon (now Sri Lanka) contained one or more unknown elements in trace amounts (42).

In her separations, Evans obtained a small amount of an unidentified dark brown sulfide. This compound she purified, then reduced to the possible newly-discovered metallic element (43). Evans attempted to determine the atomic weight of the element by means of electrolytic deposition. Working with Otto Brill, a Czech researcher with Ramsay, Evans devised a modification to the Nernst microbalance so that it could measure to as little as 0.004 mg, thus enabling only a tiny sample to be used (44). However, the results from this analytical method, and from spectroscopic analysis, proved inconclusive.

Commentary

In this work, we have endeavoured to show that, long overlooked, Sir William Ramsay was at the forefront of supporting women researchers in chemistry and of the cause of the admission to women to the Chemical Society. We hope this contribution to the literature will highlight this laudable facet of Ramsay's character.

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2018 Paul Jones Outstanding Paper Award

The winner of the 2018 Paul R. Jones Outstanding Paper Award is Seth C. Rasmussen of North Dakota State University for his paper "Cuprene: A Historical Curiosity Along the Path to Polyacetylene," *Bull. Hist. Chem.*, **2017**, 42(1), 63-78. The paper concerns the product of the polymerization of acetylene under various conditions, documenting the many attempts to both synthesize and characterize the products of this reaction.

Rasmussen received his B.S. in chemistry from Washington State University in 1990. He obtained his Ph.D. in inorganic chemistry from Clemson University in 1994, with thesis "Synthesis and Design of Conjugated Organic Metallopolymers Containing Ruthenium Chromophoric Units." He was a postdoctoral fellow (1995-1997) and an instructor at the University of Oregon from 1997 to 1999. He joined North Dakota State University in 1999 and he was promoted to full professor in 2012. Rasmussen was Program Chair for HIST from 2008 to 2017, and he continues serving the division, ending a term as Chair in 2022. He edits two book series in history of chemistry published by Springer Nature: *SpringerBriefs in the History of Chemistry* and *Perspectives on the History of Chemistry*.



MARGUERITE CATHERINE PEREY (1909-1975): THE DISCOVERY OF FRANCIUM AND THE ELECTION OF THE FIRST WOMAN TO THE FRENCH ACADEMY OF SCIENCES

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Abstract

Recent historical studies encompassing science and technology (S&T) present new and interesting perspectives on the (in)visibility of women in science. Using the methodology of the case study and with the objective of disseminating biographies of women scientists who have not achieved due recognition, this article presents an account of the personal and professional career of Marguerite Catherine Perey (1909-1975). Born in a small town east of Paris, Perey began her professional career working at the *Institut du Radium* with Marie Curie, where she later came to isolate and identify the last naturally occurring radioelement, actinium K, later called francium. The French scientist was the only woman to publish a discovery of a chemical element as the sole author and the first to obtain admission to the French Academy of Sciences. This article brings a focus to her life, to the isolation and characterization of francium and also to her election to the Academy, bringing to light not only her scientific achievements, but also her personal life and the whole struggle for due recognition.

Introduction

Since science is a human, collective and critical enterprise that interacts with the social environment in which it is produced, the development of scientific thoughts and theories is directly related to the culture in which they are generated. Therefore, it can be affirmed that the field of study involving science and technology

(S&T) is directly related to society by raising questions about scientific and technological work, as well as its connection with gender, race and social class (1, 2). Therefore new perspectives of analysis become available when one realizes that studies of S&T are not neutral but are embedded in a social structure that favors certain gender relations. Although it is now possible to see a greater female participation in science, this has not always been the case, since women have suffered—and still suffer—from exclusion and devaluation in the field. Therefore, women's limited participation in S&T is a result of historical values and ideals, rather than female unfitness for the field (3).

The 19th century, for example, was marked by the institutionalization of science, which began to have a very attractive “status” and remuneration, and men tried to keep women away from this area, characterizing it as predominantly male. In light of this, one alternative scientifically inclined women found was to work discreetly and quietly in laboratories with male relatives, acquiring secondary positions of collaborators and assistants (4).

It is worthy of note that it was also in the 19th century that the first wave of feminism occurred in France, opening doors for further transformations in this scenario (5). Thus, the search for the inclusion of women in the most diverse fields of knowledge begins to locate more examples at that time, reflected in changes throughout the following century, such as the election of Marguerite Catherine Perey (1909-1975) to the French Academy of

Sciences in 1962. The academy, founded in 1666, carried a legacy in which women were not accepted as members, and Perey became the first female scientist to be admitted to the institution (6).

Marguerite Perey, shown in Figure 1, was a French scientist of humble origins who began her professional career at the age of 19, working with Marie Sklodowska Curie (1867-1934) at the *Institut du Radium*. It was during her research at the institution that Perey identified the last naturally occurring radioelement, francium, and was the first and only woman to single-handedly sign the disclosure note for a chemical element (6).

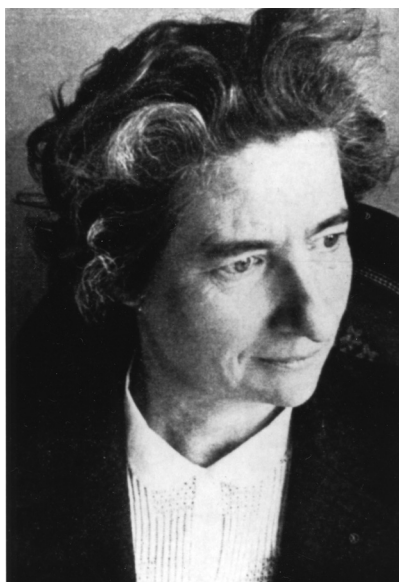


Figure 1. Marguerite Catherine Perey in 1962. Credit: AIP Emilio Segrè Visual Archives, Gift of J. P. Adloff

Still in the case of France, in the beginning of the 20th century women gained some rights, such as the power to vote and the right to assume political positions. Moreover, French feminism gained even more strength in the 1970s, enabling its expansion into social and scientific fields that no longer continued the exclusion of women and questioned the gender inequality imposed for so many years (5).

In the 21st century, relevant transformations in this scenario are being observed and women have begun to reach positions of prominence and influence (7). Thanks to the dedication of historians of science and other historians who reconstructed this trail, it has been possible to rescue the first steps of women's insertion in the scientific and technological environment, and it is possible to contest their (in)visibility in the area (8).

The lines of study and research are no longer about an undifferentiated “gender and science” but about

“gender in science,” bringing historiographical studies that recognize such issues involved in the field (9). Thus, it is necessary to map, diagnose and contest both the absence and the presence of women in the scientific and technological sphere over the years. Therefore, this article seeks to reaffirm the importance of recognizing the female presence in science by bringing a detailed approach to the life and career of Perey, the woman responsible for the discovery of the chemical element, francium, and the first woman to be a member of the French Academy of Sciences.

From Childhood to Studies with Marie Sklodowska Curie (1867-1934)

Marguerite Catherine Perey was born on October 19, 1909, in a small town in the suburbs of Paris, France, called Villemomble. She lived with her father, Louis Émile Perey (1856-1914), her mother, Anne Jeanne Perey (1858-1951), three brothers and a sister, constituting a humble family whose source of income was the work done in a flour mill on the farm where they lived (6). In 1914, after a stock market collapse caused by the outbreak of the First World War and the death of her father, Marguerite and her family began to face financial difficulties. As a result, at the age of 15, she started a job as a tutor for students of the Lycée—those whose age is between 15 and 17 years old, and may extend until 18 years old, corresponding, therefore, to High School in Brazil or in the USA—while her mother gave piano lessons. However, the precarious financial situation of the family did not allow any of the siblings to enter higher education, and Marguerite had to abandon her dream of becoming a doctor (10).

In January 1917 the *École d'Enseignement Technique Féminin* was founded in Paris. The institution had as one of its main objectives the training of girls in the most varied branches of technology (11). It was in this technical school that, in 1928, Perey began her studies in chemistry, believing that such an opportunity was the closest she would get to a higher education. However, what she did not imagine was that the technical school had a partnership with an important scientist of the time, Marie Sklodowska Curie, who established that whenever financial funds were available, the best student of the class would be invited to work at the *Institut du Radium* in Paris under her supervision (12).

In June 1929, Perey and her classmates received the *Diplôme d'Etat de Chimiste*, equivalent to a diploma in chemistry and, in the same month, the winner of the

Nobel Prize for Physics (1903) and the Nobel Prize for Chemistry (1911) went to interview the newly graduated laboratory technicians. Perey reports that, after being directed to a small, dark room, a woman with glasses, grey hair tied up in a bun, and dressed entirely in black, entered the room. When she realized that it was Madame Curie, Perey felt inhibited and embarrassed to be in her presence (6).

After an interview, considered by Perey to be somber and melancholic, the French graduate was completely sure that it would be the first and only time to be in the presence of Curie. This was because she believed that she had no university studies, and also would not be invited for the position because of her little experience in the laboratory. However, in July of the same year she received a letter informing her that she had been called to the institute, which caused her great surprise and enthusiasm (6).

Although she had been trained to perform simple chemical operations and prepare trivial products using “kitchen containers,” Perey stood out for her intelligence, enthusiasm for learning and remarkable laboratory skills. Such qualities helped to distinguish her from her laboratory colleagues, contributing to her first professional promotion: she became Curie’s personal assistant. Thus, she began her scientific career at the age of 19, being commissioned to work on the purification of the chemical element actinium (13).

This element was discovered in 1900 by André-Louis Debierne (1874-1949) after analyses of pitchblende residues. Curie then decided to turn her studies to spectroscopy of the actinium series. However, the element had an uncertain half-life, ranging between 7 and 22 years, and to study it a concentrated sample was needed, from which it would be separated from all the other components of the uranium ore (14).

Thus, Curie asked Perey to prepare a sample, as concentrated as possible, of the chemical element, and then begin the physical-chemical analyses. In 1934, after numerous precipitations and fractional crystallizations, finally a sample of 5 mg of lanthanum oxide containing 0.053 mg of ^{227}Ac was obtained. However, the research was halted due to the death of Curie (6).

Work at the *Institut du Radium* and a Brief Account of the Discovery of Francium

After Curie’s death, Debierne took over as director of the *Institut du Radium* and began to guide Perey’s work

on actinium (^{227}Ac) with the assistance of Irène Joliot-Curie (1897-1956). The focus of Perey’s research was to determine the exact half-life of the element. Because the decay of ^{227}Ac could not yet be measured directly (as its beta (β) radiation was too soft to be detected), a waiting period of 3 months was required for the establishment of the radioactive equilibrium between it and its daughter nuclei, whose decay could be observed (14).

In 1938, when Perey began analyzing the lanthanum oxide sample obtained 4 years earlier, she observed during the first few hours a penetrating β activity that grew in an interval of 21 min, differently from all activities of the actinium decay sequence. Thereafter, such activity reached a plateau and then slowly increased again. From this, two conclusions could be drawn: the observed activity did not correspond to ^{227}Ac (for it would not have had to grow in) and, as expected, radiation of that element could not be measured under the conditions imposed (for no activity was observed immediately) (15).

Perey then decided to perform the procedures again in different equipment and conditions and still continued to obtain the same results. When she again precipitated all the actinium descendants and tested their activities, none of them presented an increasing beta activity over a 21-min period, which led her to think that the measured radiation was related to a product generated by the radioactive decay of actinium itself, that, although it was purified and free of interference, again indicated the presence of this specific daughter nucleus in the sample (16).

When the purified actinium was left to stand for two hours, then placed in solution and precipitated again with cesium perchlorate, a beta activity that decreased over a period of 21 min was observed, differently from what had been observed before. In view of this, Perey could only reach one conclusion: the increase in the activity of the penetrating beta type observed was related to the presence of a new chemical element, which had not yet been identified (16). According to the laws of displacement, the new chemical element was that with atomic number 87, formed by the alpha (α) decay of ^{227}Ac , called Eka-cesium (Eka-Cs) as a placeholder name. To this isotope of Eka-Cs, Perey gave the name Actinium K (AcK); the 21-min period was the half-life for the decay of AcK. Perey later found that the proportion of actinium atoms decaying to AcK was about 1.2% (17).

At the age of 29, Perey discovered the first isotope of Eka-Cs with mass number 223 and, upon informing her advisors of the discovery, a note was published in the *Comptes rendus* of the French Academy of Sciences for

9 January 1939, with the title “*Sur un élément 87, dérivé de l’actinium*,” in which Perey is listed as the sole author (14). Figure 2 shows one of the rare images of Perey at the *Institut du Radium* at about this time.

However, as expected, the presence and acceptance of women in the field of science was not easy, and with Perey it was not different. The scientist and Nobel Prize winner (physics 1926) Jean Baptiste Perrin (1870-1942) publicly downplayed Perey’s discovery (18) and promoted a prior claim to the discovery of element 87 by his former students Horia Hulubei (1896-1972) and Yvette Cauchois (1908-1999). Hulubei, who had called the element moldavium, claimed that it was a stable but very rare element (19). Perrin dismissed Perey’s discovery, calling it a “fleeting chemical element.” Hulubei and Cauchois were only the latest to claim to have detected a stable element 87 (20), claims that were finally refuted in the 1940s.

Perrin was the one who presented Perey’s studies to the French Academy of Sciences on 9 January 1939. (Work by scientists who were not members of the Academy was typically presented to the Academy by members; Perrin was a member.) The end of Perey’s paper in the *Comptes rendus* (16) cites the prior claim by Hulubei and notes that, if confirmed, it would be a long-lived isotope of the same element she was reporting. On the surface, these words appear appropriate—an acknowledgment, though not an acceptance, of relevant prior work. Perrin’s criticism certainly rankled, though (15). One wonders if the citation of Hulubei in Perey’s paper was at Perrin’s behest.

Perrin’s skepticism of Perey’s discovery influenced the same sentiment in the scientific community at the time, but Perey continued her studies on the element with atomic number 87. In Perey’s words (quoted in 21):

Even if the period that followed my identification of francium brought certain honors, I also went through moments of tears and disappointments caused by vile traits of human character: manifestations of baseness and perfidy.

The Life of Perey after the Discovery of Actinium K

After the discovery of AcK, Perey decided to continue investigating the radiations emitted by the new radioelement and, in 1941, established that approximately 1% of its atoms emit gamma (γ) radiations (22). Five years later, she conducted another study about the radioactive

products of $^{223}_{87}\text{AcK}$ (23) in which she found that it was formed by the α -emission of actinium and that, when it disintegrates by β -emission, it transforms into AcX (24).

It was also after the discovery of the radioelement that Debierne and Joliot-Curie encouraged Perey to begin her university studies. Although she did not obtain an undergraduate degree, the scientist had enough material to submit a doctoral thesis, but a *license* was first required. Then, between the years 1942 and 1945, Perey obtained three certificates whose chosen subjects were physiology, biology and chemistry, making her qualified for her defense (15).

In 1946, more precisely on 21 March, Perey defended her doctoral thesis entitled “*L’élément 87: Actinium K*,” at the *Université de Paris*, under the assessment of Debierne, Joliot-Curie and Pierre-Paul Grassé (1895-1985), biologist and member of the French Academy of Sciences. In the last line of her thesis, Perey suggested the name *francium* (Fa) for the newly discovered chemical element. However, during the defense of her thesis, the scientist suggested the name Catium (Cm), an idea approved by Debierne, but Joliot-Curie believed that this name could be suggestive of *cat*, and not *cation*. Therefore, Perey chose to name the chemical element with atomic number 87 as francium (15).

In late 1946, Perey was invited to work at the *Centre National de la Recherche Scientifique* (CNRS), the largest public scientific research body in France, located in Paris and founded in 1939 with the help of Joliot-Curie. Perey was commissioned to teach a course on spectroscopic methods, but she had no intention of becoming a teacher, which left her dissatisfied with her responsibilities. Her main motivation was to continue research on francium and as a result, had intended to recruit research students, which was not allowed at the *Institut du Radium* (6).

So, she decided to give up her position at CNRS when she was appointed to the chair of Nuclear Chemistry at the Faculty of Sciences of the University of Strasbourg in 1949. There she was entrusted with the new task of creating a nuclear research laboratory to study chemical and biological applications of radioactive isotopes. And still in the same year, she started a regular course called “Chemistry and Physics of Radioelements,” excelling in teaching laboratory techniques to manipulate, purify and measure radioactive compounds (17).

In January 1951, Joliot-Curie opened the modest research laboratory in Strasbourg and, together with the young physicist André Coche (1922-1997), Perey

undertook theoretical and practical training on radioactive transformations, nuclear physics and instrumentation. Before long she accepted her first research student, Jean-Pierre Adloff (1930-2019), a dedicated student who would become one of the greatest admirers of Perey's career, being responsible for several of the articles published about her life (10).

In view of this, Perey and Adloff decided to study new methodologies for the separation and identification of francium that were fast and efficient, offering the purest possible sample. The scientists determined that to obtain pure francium it was sufficient to perform a paper chromatography for 10 min with an actinide product. Thus, the desired radioelement was extracted from the bottom of the filter paper by immersion in water, establishing an isolation method without the need for a waiting time of three months until radioactive equilibrium between the elements of the actinium family (25, 26).

In 1955 the university and the CNRS decided to group all the laboratories responsible for nuclear studies from various locations into a single research center. The *Centre de Recherches Nucléaires* (CRN) was divided into four sections led by university professors: nuclear physics, particle physics, nuclear chemistry and biological applications; Perey was in charge of the nuclear chemistry department. This contributed to the emergence of new professional opportunities, such as election to the French Academy of Sciences—the first woman to achieve such a feat (6).

The History of the French Academy of Sciences and the Election of Perey

In 1666, Jean-Baptiste Colbert (1619-1683), a French minister during the reign of Louis XIV (1638-1715), founded an Academy dedicated to the development of sciences which was named, years later, the Royal Academy of Sciences. Then it was composed of 70 members appointed by the king and 80 corresponding members who held prominent positions in certain areas. It was one of the major contributors to scientific expansion at the time (27). The Academy was suppressed by the Convention during the first French Republic, and shortly thereafter a national institute was established for arts and sciences. Early in the 19th century, the name Academy of Sciences was once more applied to this branch of the *Institut de France*. With the advance of science in the 20th century, the number of members began to grow, and modifications and innovations began to appear, such as, eventually, the election of the first woman to

the Academy. The institution carried a legacy in which women were not elected as members, and not even Marie Curie managed to escape this prejudice when she lost her election as member in the general physics section to Édouard Branly (1844-1940) in 1910. However, with the election of mathematician Arnaud Denjoy (1884-1974) as president of the academy in January 1962, a series of structural changes were adopted, some of which may have lowered barriers to the admission of women (28).

On 12 March 1962, the academy elected Marguerite Catherine Perey to the physics section, over the dean of the Faculty of Sciences of Marseille. Perey was elected by a tally of 48 votes to 13. This established the election of the first woman to the French Academy of Sciences. But behind the election there was a detail that was not reported by the newspapers of that time: Perey was elected as a corresponding member, not a full member (28).

It should be noted that the corresponding members, also called second-tier members, did not hold “academic chairs.” In other words, they were not part of the academic corporation and even less did they receive the title of academician which was reserved for the 40 members of the *Académie Française* (the most exclusive body of the *Institut de France*). Considered “immortal,” they symbolized talent, intelligence, culture, literature and the French scientific imagination. On the other hand, they possessed the right to deny the acceptance of papers submitted for weekly publications in the *Comptes rendus* of the academy (28).

Perey was aware that her election would be breaking barriers to the inclusion of other women in positions previously dominated by men. And that is really what happened. Sixteen years later, physicist Yvonne Choquet-Bruhat (1923-) was elected as corresponding member in the mechanical and computer sciences section and, one year later, was appointed full member, the first woman to hold that position (29).

As this article goes to press, the Academy has 268 members, 121 foreign associates and 62 corresponding members, composing a multidisciplinary assembly. The Academy is composed of two divisions: Mathematics, Physics, Mechanics and Computer Science, and Earth Sciences and Astronomy; and Chemistry Molecular and Cell Biology and Genomics, Integrative Biology, and Human Biology and Medical Sciences. According to data available on the Academy's official website, in 2022 there were only 2 women elected members in the Chemistry section: Odile Eisenstein (1949-) and Janine Cossy (1950-), Eisenstein being the director of the section (30).

This organization, which celebrated its 350th anniversary in 2016, provides advice and sponsors debates in the face of the ethical, political and social challenges posed by science, in order to always support the development of research, commit to the quality of science teaching and be present in the international scientific environment.

Perey's Later Years

With the election to the French Academy of Sciences, Perey became the target of newspaper and magazine articles about her personal and professional life. With these, the first rumors arose that she was secretly suffering from a disease feared by all scientists who worked with radioelements: cancer (28).

Shortly after settling in Strasbourg, Perey began to experience symptoms that, after about a decade of increasing frequency and intensity, led her to abandon her research activities in the laboratory in 1960. By that time she was feeling strong pains throughout her body, especially in her hands. Examinations showed that after years of radiation exposure, Perey's body began to show signs of the presence of radiation characteristic of actinium and all elements of its family in her entire bone structure (14). To treat the illness, Perey moved to Nice, situated in the Côte d'Azur region on the Mediterranean coast of France, and made sporadic and brief visits to Strasbourg to fulfil her professional commitments. Although she knew it was a disease that compromised her movements and bone structure, she never gave up hope of returning to work. Unfortunately, the disease only progressed after that (28). In one of the letters she wrote to her research student, Adloff, in 1961, Perey reported that she was feeling the effects of radiation even more intensely and regretted the fact that she could no longer resume her research (6).

On 13 May 1975, Perey, the only woman to single-handedly sign the discovery of a chemical element and the first woman to be elected to the French Academy of Sciences, died (13). It is worth noting that, still in her lifetime, Perey was nominated for the Nobel Prize in Chemistry at least five times: 1952, 1958, 1961, 1965 and 1966. She never won it; wouldn't that be another gender issue (31)?

However, the French scientist received decorations and awards that recognized and validated her professional achievements, such as the Leconte Prize of the French Academy of Sciences (1960), a French honorary

decoration called the National Order of the Legion of Honor (1960), the Silver Medal of the French Chemical Society (1964) and, lastly, in 1974, the French National Order of Merit (13).

Concluding Remarks

As reported at the beginning of this article, the (in) visibility of women in the field of science and technology is mainly due to structural sexism. Although considerable changes are being seen in the 21st century, there is still a long way to go, especially in science and technology. The examination of women's stories in science helps in this reflection. Moreover, this examination demonstrates scientific praxis and how it is still determined by masculine values and ideals, devaluing the work developed by female scientists as compared with male scientists. Thus, it is essential to approach the trajectory of women who have contributed to the development of science, bringing to light not only their scientific achievements, but also their personal lives and the whole struggle for due recognition.

Perey is an example of a female figure who contributed significantly to the advancement of science, yet did not achieve due recognition. In addition to being the only woman responsible for the discovery of a chemical element alone, she opened the door to female participation in the French Academy of Sciences. As mentioned earlier, even though she did not receive a position of the highest rank, her appointment brought important changes at that time, opening new opportunities for women scientists who still encountered gender prejudice in academia.

In view of this, we again reinforce the relevance of publicizing biographies of women scientists in order to break the conception that they are invisible in science, since they do not receive due recognition for their work, as men scientists do. Therefore, in this perspective, the discussions about science, technology and gender gain even more strength, opening space for works in the field of history of science such as the one presented here.

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2019 Paul Jones Outstanding Paper Award

David E. Lewis of the University of Wisconsin-Eau Claire is the recipient of the 2019 Paul R. Jones Outstanding Paper Award (OPA) for his paper "1860-1861: Magic Years in the Development of the Structural Theory of Organic Chemistry," *Bull. Hist. Chem.*, **2019**, 44(2), 77-91. Lewis previously received the OPA for 1997 and for 2010. The prize paper is the written form of Lewis's HIST Award address for 2018. It chronicles the dramatic improvement in understanding of structural organic chemistry in the years 1860-1861. All the key figures are discussed and contextualized, with the work of Butlerov and Markovnikov highlighted.

Lewis graduated with honors in organic chemistry from the University of Adelaide, South Australia, in 1973. In 1977 he completed his Ph.D. from the University of Adelaide after he had moved to the University of Arkansas as a research associate. In 1981 he joined the faculty of Baylor University in Waco, Texas, earning tenure in 1988. He then went to South Dakota State University where he was promoted to full professor. He moved to the University of Wisconsin-Eau Claire in 1997 from which he retired in 2022. Meanwhile, he earned a D.Sc. from the University of Adelaide in 2012. He was awarded the Markovnikov Medal in 2019. Lewis served as Chair of HIST in 2003-2004.



HIST CENTENNIAL MEMORIES

PAUL RAYMOND JONES (1930-2019)

Sarah Cummings, Amy Robinson, and Martin Saltzman; Edited by Carmen J. Giunta, Le Moyne College, Syracuse, NY, USA, giuntacj@gmail.com

Introduction

As promised in the HIST Centennial special issue of this journal, the *Bulletin* is running centennial features in each of its 2022 numbers (1). The next 2022 issue featured Aaron Ihde, Chair of the division in 1962-1964 (2) and included a reminiscence of George Kaufmann (3). This issue recalls Paul Raymond Jones, Chair of HIST in 1994 and Editor of this journal from 1995 through 2010. After his death in 2019, the award for the outstanding paper published in the *Bulletin* was named the Paul R. Jones Outstanding Paper Award.

After a brief review of Jones's career, this feature includes recollections from one of his graduate students and another HIST Chair (1995), Martin Saltzman (4), and reflections from his daughters, Amy Robinson (5) and Sarah Cummings (6) given at his memorial service in 2019.



Figure 1. Paul R. Jones (1930-2019). Courtesy of Sarah Cummings.

I add only that getting to know Paul during my early years of engagement in the division was a genuine pleasure, and that succeeding him as editor of this journal has been an honor and a privilege. —Ed.

Biographical (7)

Paul Raymond Jones was born on July 19, 1930, in Chicago to David Henry and Una Goodrich Jones. He grew up in nearby Park Ridge, Illinois. He received a B.A. in 1952 from Albion College in Albion, Michigan. He returned to Illinois for his doctoral work in chemistry, earning a Ph.D. from the University of Illinois in 1956.

That year he began a nearly 40-year career as professor of organic chemistry at the University of New Hampshire. He was an accomplished researcher, publishing regularly over the next 25 years in such respected journals as the *Journal of the American Chemical Society* and *Journal of Organic Chemistry*. He was twice a Fulbright

scholar, and four different sabbatical leaves brought him to Germany: at the Max Planck Institute in Göttingen (1964), at the University of Freiburg (1973), and twice at the Deutsches Museum in Munich (1982 & 1991).

Teaching and connecting with students were important to Jones. Even in very large lecture classes, he knew all his students by name and always made himself available. The University of New Hampshire conferred its Distinguished Teaching Award on him in 1982. *The Journal of Chemical Education* published a series of cartoons by Jones and Brian Coppola in the late 1970s under the title “Animated Alchemy.” Figure 2 shows a drawing Coppola made of Jones at about that time.

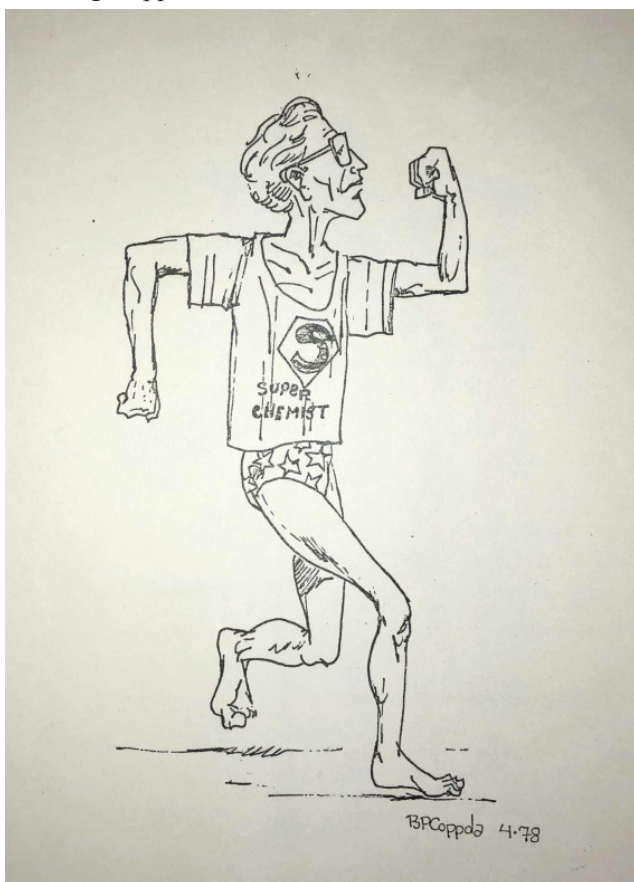


Figure 2. Paul Jones portrayed as Super Chemist by Brian Coppola, 1978..

History of chemistry was one of Jones's scholarly interests from at least 1970 when he and Everett Southwick published a translation of a 1901 paper by Victor Grignard based on his dissertation (8). His first sabbatical at the Deutsches Museum led to a monograph published by the Museum on chemistry doctorates earned in nineteenth-century Germany by anglophone chemists (9).

In 1995, Jones retired from the University of New Hampshire and began another chapter of his academic

career, serving as the editor of the *Bulletin for the History of Chemistry* from 1995 to 2010.

Jones married Meredyth Manns in 1958. They moved to Ann Arbor, Michigan, shortly after his retirement from the University of New Hampshire. In 2013 they moved to Ithaca, New York, to be closer to family. Jones died on January 3, 2019 after a period of declining health. The Joneses raised three children, Paul, Amy (now Robinson) and Sarah (now Cummings).

Recollections by Martin Saltzman (4)

Paul was a true gentleman and scholar who treated everyone with respect and dignity. He saw himself as an educator first and not a person who wanted to advance his career on the backs of his students and colleagues.

I think it is best to concentrate on what Paul did when he retired with respect to the History of Chemistry, on which we collaborated over many years.

Paul's first major contribution occurred when he spent a sabbatical year at the Deutsches Museum in Munich, where he compiled an authoritative list of British and American chemists who obtained their doctoral degrees in Germany in the nineteenth century. This compilation was published in booklet form by the museum (8) and was used as a primary resource by many researchers interested in the influence of German education in the development of American and British graduate and post graduate education.

In doing this study Paul became interested in the connection between Justus Liebig and one of his early American students, Eben Horsford, who was one of the first German-trained chemists in the United States. Horsford was professor of chemistry at the Lawrence Scientific School associated with Harvard College (10).

Horsford is credited with the invention and commercialization of baking powder as an alternative to the use of yeast. He was instrumental in founding a commercial plant to produce baking powder. This plant was built in a section of East Providence, Rhode Island, known as Rumford, and the company took this name. The plant still stands, but the making of baking powder ceased many years ago, and the building was being redeveloped for other purposes. Paul and I wrote a proposal to designate the old Rumford baking powder plant as an American Chemical Society National Historic Chemical Landmark. A plaque now is attached to the entrance of the old administrative building denoting the significance

of the site (11).

I think Paul's major long-term achievement was when he took over as editor of the *Bulletin for the History of Chemistry*. This was the official publication of the division, and it had reached a point where its production had become erratic and the *Bulletin* may have ceased publication. Paul volunteered to take over, and because of his work put the *Bulletin*, which appeared twice a year, back on a sound standing. Paul was always willing to add his absolute mastery of the English language and grammar to those of us who were less adept in a kind and gentle fashion. Papers were reviewed in a timely manner and he always had words of encouragement to contributors for their efforts.

Family Remembrances



Figure 3. Paul Jones as a child.

[From Amy Robinson, daughter (5)]

My father's childhood had adults in it who could only be described as chaotic and dark for a sensitive boy, but the miracle of his life was that his gentle spirit and determination did not give into that legacy. And he embraced the light as if his very life depended on it.

He embraced the light of literature and was transported by Thomas Wolfe, Willa Cather, Ivan Doig, Charles Dickens, Wallace Stegner, and so many others. In fact he kept a log of books read since he retired in 1995 and I counted them: 461. He found joy and solace in the poetry of Emily Dickinson, Edna St. Vincent Millay, Mary Oliver and Shakespeare's sonnets, and he wrote many poems of his own. He had a genuine unaffected, intellectual curiosity.

He embraced the light of art and would make sure to find a museum in whichever city his chemistry conferences found him. He loved the impressionists, especially Pissarro, and adored Andrew Wyeth, making more than

one pilgrimage to Christina Olson's home in Cushing, Maine.

My father embraced the light described in Mary Oliver's poem "One or Two Things" as the "god of dirt" and never lost his excitement for a new season of growing vegetables, yes, but particularly flowers. Peonies were his favorite, and he was well known for sharing their perennial roots among friends and family, though he found it melancholy that their presence each year was so fleeting. Nasturtiums were his second favorite, especially since they persevered all through the summer and fall, and even last year he kept me updated every week about how his were doing on the stoop outside his apartment. "Isn't it amazing?" he would say every year, "that just a tiny dry seed produces something so gorgeous?"

He embraced the light of personal relationships and found great joy in hearing another's story, always with sincere interest and offering his undivided attention. If you were a guest in my parents' home, Dad would refill your water glass before you realized you were thirsty and nudge the butter dish closer if you took bread. My siblings and I have heard from scores of students who may not recall much organic chemistry but they remember his kindness, that he knew their name and details about their family even years later, and that he consoled them when they cried in his office, usually telling them to just get more sleep.

Dad embraced the light of progressive change—as long as it did not include the degradation of grammar, fewer men wearing collared shirts, the loss of the Palmer method of penmanship or any criticism of the British Royal Family. When the Supreme Court upheld gay marriage he was the first person I wanted to call and we cried tears of joy. Championing causes which furthered human rights, he read with interest and discussed many articles against bigotry, homophobia and hate—though if his beloved *New York Times* published an article which misused the Oxford Comma, he cut it out and put it in a file marked "The Oxford Comma."

He cherished the light of his family, both his ancestors and those of us still here. He took us on trips, treated us to dinner, and plumbed us for details of our lives with uncompromised attention. What did we think about politics? What were we working on? What were we reading and seeing in theaters? And what or whom did we love? Dad had a deep sense of history and never tired of his genealogy projects, not because he cared about prestige but because he cared about stories and connections. We spent a number of sabbatical years in Germany and he

treated us to plenty of schnitzel and almond cake with cream, but he also made sure we understood deeply and at a young age, the disastrous effects of National Socialism.

Dad embraced the light of his religious faith. His father was adamantly against the church, but Dad, as a nine-year-old boy, went to the local Lutheran church all by himself. The Community Church in Durham, the Presbyterian Church in Ann Arbor, and this one we are in now [First Presbyterian Church of Ithaca, New York] were the center of his social and spiritual life, particularly the ministry of music through his beloved wife Meredyth.

...



Figure 4. Paul Jones celebrating his 50th wedding anniversary, wearing a paper hat made by his grandchild. Courtesy of Sarah Cummings.

[From Sarah Cummings, daughter (6), on music]

Paul Jones's life changed forever in 1952 when a close friend loaned him a record he thought my dad might like. This was around the time he started graduate school, and it was a pretty lonely time for him. All of his fraternity buddies from Albion College had gone off to law school at the University of Michigan but Paul headed to the University of Illinois to study chemistry, which was academically the better fit for him. Against that backdrop of loneliness came the gift of this record, which contained

the *Adagio for Strings* by Samuel Barber. In short, it blew him away. For this 22-year-old, extremely sensitive young man who felt things very deeply, this piece of music pierced his very soul. The only negative aspect of the listening experience was that he had to jump up quickly to lift the needle before the next piece came on—David Diamond's *Rounds* for strings, a thoroughly "modern" piece which in Dad's mind ruined the spell cast by the transcendent Barber. As time went on, Dad thought of his life in terms of before and after he had heard the Barber for the first time; it was clearly a real turning point for him. Dad spent the rest of his life trying to understand the piece, at least ostensibly. He was fascinated that it didn't end on the tonic note; the ending really filled him with wonder and awe. "I think it must be modal," he would insist, though what mode it was exactly was never clear to him. He was happy when a music theorist joined the family and could try and help him get to the bottom of what made the piece work...but no matter how it was explained to him, no answer really ever satisfied him. In retrospect, I actually think he didn't really want to unlock what made it so special; maybe the scientist in him wanted to know, but the human being wanted to keep the piece on a whole other intangible level.

Dad was one of those adults who always wished they had stuck with their childhood piano lessons, in his case, with Mrs. Breivogel, a nearby neighbor. Even though he stopped taking lessons for whatever reason, he could always bring out his one-handed renditions of *Sunshine Showers* and *March of the Wee Folk*, but he was consistently frustrated that he couldn't do more. While living in Ann Arbor, Dad wrote this about his struggle to express himself musically and his regret in quitting the piano: he wrote "I can experience with genuine pain what I wish I were able to produce in the form of soaring, or gentle, or moving musical beauty—yet hear it only, with idle, talentless fingers."

Singing soon began to fill that void. He sang in choirs in college and in graduate school and even sang under the great Leopold Stokowski while at the University of Illinois. He was an active choir member in the Presbyterian Church of Urbana throughout his graduate school years. When he got a job teaching chemistry at the University of New Hampshire in 1956, he soon found the Congregational Church in Durham and joined the choir right away.

And then he met Meredyth, who became his beloved wife of 60 years and everything changed. I don't think it's an exaggeration to say that through Meredyth, his musical dreams were fulfilled. Mom was a musical

force of nature; in addition to conducting the Durham Community Church choir for 35 years, she started a big community chorus which put on large-scale productions every year and she also led a small select group of singers. This “small group” had initially been Dad’s suggestion: “let’s invite a few people over to sing madrigals,” he had said, and the next thing he knew, it had blossomed into Amare Cantare, a select 24-voice group that toured all over the state of New Hampshire. Dad was Meredyth’s most enthusiastic supporter and could not have been more proud of all that she did: he sang faithfully in each of her groups, which usually meant going out to evening rehearsals three or more times each week. He was also the ultimate wingman, doing whatever needed to be done behind the scenes without complaint: transporting the harpsichord, typing out programs, hanging posters all over town, hosting parties, learning Shaker dances and wearing tights at an Elizabethan Feast. In a collection of memories gathered for Dad’s 85th birthday, Mom wrote “You were always the best possible choir tenor; never harsh and always blending.” Though he belittled his own musical expertise, he had an innate sense for the creation of music versus just the production of notes. He had strong opinions and astute observations about conductors, especially choral conductors, and the only thing that mattered was how they shaped the phrase, showed the line, drew the music off of the page. Honestly, I think he was secretly always comparing other conductors to Mom as the ultimate musical conductor; showing music, and not beating notes. I think when all was said and done, she was his favorite conductor.

My father was many things: a curious scientist, compassionate teacher, devoted husband, patient father, but I really feel he had the soul of an artist. He loved and appreciated beauty in every form: art, literature, poetry, in his garden, the natural world, and yes, music. He loved Frank Sinatra, the Four Freshmen, Beethoven String Quartets, Vaughan Williams Symphonies, Leonard Bernstein’s Mass, the Fauré Requiem, Bach’s St. Matthew Passion, and choral music of all kinds. He was never snobbish about this interest, rather always genuinely curious to know more about composers, history, and biography and in recent years, when he had time to read the *New York Times* cover to cover each day, he would always save clippings for me on what was going on in the classical music world. Together with Meredyth, he was an ardent supporter of the arts in his community, wherever he lived and was an avid concert-goer. On one occasion, as a member of the concert committee at UNH he even had the opportunity to iron Itzhak Perlman’s pants at the last minute just before a performance!

I would invite you to take a moment to remember Paul by putting on a recording of the *Adagio for Strings* by Samuel Barber. Many of you might have associations between this piece and war, destruction, and mass devastation, due to its wide use in the movies and after 9/11. Whether you have heard the piece before in any of these contexts or are listening to it today for the first time, I invite you to listen to it through the lens of a wide-eyed 22-year-old young man setting out on the world, a man who felt “O World, I cannot hold thee close enough,” for whom art, literature, nature, faith and music cut to his very core. For Paul Jones, this is a piece about hope, beauty, the connection between human beings, and above all, wonder.

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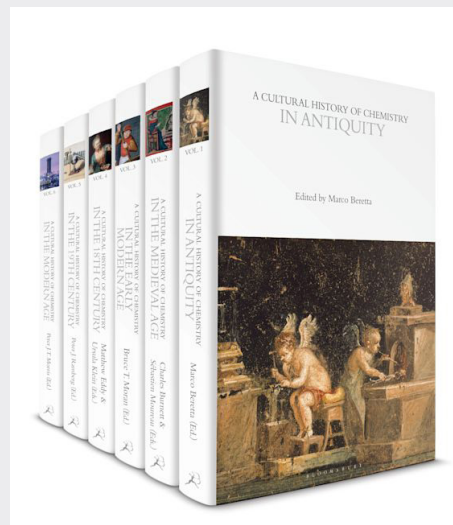
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BOOK REVIEWS

A Cultural History of Chemistry, Peter J. T. Morris and Alan Rocke, General Editors, Bloomsbury Publishing, London and New York, 2022, 6 vol., ISBN 9781474294928, \$550.

We are pleased to bring our readers reviews of all six volumes of the recently published *A Cultural History of Chemistry*, edited by Peter J. T. Morris and Alan Rocke and published by Bloomsbury. This set is part of a larger Cultural Histories series published by Bloomsbury over the last couple of decades. Currently the work is available only as a six-volume set, except for volume 1, which is available online open access at Bloomsburycollections.com. It is expected that separate volumes will be available for purchase in 2023.

What is cultural history? To quote cultural historian Peter Burke, “The question was asked in public more than a century ago, in 1897 For better or for worse, it still awaits a definitive answer.” Burke does not stop there, though, on page three of a 188-page book titled *What is Cultural History?* first published in 2004 and now in its third edition. The field is marked by a diversity of subjects and approaches, but their common ground is a focus on the symbolic aspects of a subject and their interpretations. Cultural history can also pay special attention to practices. Yet another interpretation of the term cultural history is synonymous with social history, one which concentrates on institutions and other types of society.

So what kind of cultural history have Morris, Rocke, the volume editors and the chapter authors produced? The description of the series promises to examine ways in which chemistry has influenced society, including trade,

warfare and medicine, as well as how chemistry has been affected by such products of society as technologies, institutions and cultural beliefs.

A more detailed idea of the scope of the project can be gleaned from its organization along both temporal and thematic lines. Each volume is devoted to a different historical period named in the volume’s title: antiquity, the middle ages, the early modern age, the eighteenth century, the nineteenth century and the modern age. Each volume treats the same eight themes in chapters bearing the same title (but different subtitles) in each volume. These are Theory and Concepts, Practice and Experiment, Laboratories and Technology, Culture and Science, Society and Environment, Trade and Industry, Learning and Institutions, and Art and Representation. Thus the themes span several aspects of the term cultural history, from symbols to practice to society.

With no further ado, let us proceed to the reviews.
—Editor

Vol 1: *A Cultural History of Chemistry in Antiquity*, Marco Beretta, Ed., xii+300 pp

Although no explicit definition of the cultural history of chemistry is offered by either the authors or the editor of this volume, nor of the other five volumes of this series, I infer a far broader swath than, for example, the history offered by Bernard Jaffe’s *Crucibles: The Story of Chemistry* (1) or Aaron Ihde’s *The Development of Modern Chemistry* (2). For me, a cultural history is contextual, taking into account not only specific events or periods, like Ihde’s book, or personalities, like

Jaffe's work, but also practices, techniques, equipment, ideas, philosophical assumptions, beliefs, experiences, economy, trade, and societal attitudes and values. This broad view encompasses virtually every topic covered by J. R. Partington's monumental four-volume *A History of Chemistry* (3), yet so much more. Each of the eight chapter headings, identical across all six volumes, encompasses my personal stated vision of a cultural history. The approach of the volume is unique as well. Each chapter is divided into four parts. Three of these parts are geographic, viz., Egypt, Mesopotamia and the Greco-Roman World, written by Sydney H. Aufrère, Cale Johnson and Matteo Martelli, respectively; the final part, Conclusions, is authored by Marco Beretta, the editor of the volume. The editor explains the reason behind this choice of format in his introduction: covering 3000 years of history and the interactions of three distinct civilizations required three highly specialized competencies in the persons of the three selected authors.

It turns out that defining chemistry is every bit as difficult as defining cultural history, however. Galileo once said that science "is written in the language of mathematics" (4), yet every practitioner of the "divine art," i.e., today's "chemistry," knows that measurement is necessary but not sufficient to describe its methods. Partington wisely agrees: "Chemists should always be interested in the attempts of mathematicians and physicists to explain the fundamental laws of chemistry which have been arrived at by methods peculiar to the science, but if they are wise they will continue to use these laws... even though they cannot yet be reduced to terms of concepts which seem rather foreign to the content of chemistry" (5). The authors of this volume, faced with a pre-history of chemistry where the concept of measurement was more commercial than ontological, relied on descriptions of practice, language, production, technological breakthroughs, experiment, complex classifications of substances, innovations in apparatus, exchange of intellectual property, dissemination of technical literature and iconographic analysis to tell their story.

Chapter 1, Theory and Concepts: The Mythological Foundation of Chemical Theories in Ancient Civilizations deals with the ancient mind, imbued with myths of goddesses and gods, coming to grips with the relationship of these myths to the material world. In Egypt, a physical substance could refer to the very nature of a god, whereas in Mesopotamia, the importance of the substance was subservient to the economic impact of the finished product. An important part of Mesopotamian first millennium BCE scientific tradition consisted of descrip-

tive lists of the properties of plants, minerals, and other categories, sometimes amounting to thousands of items. A different approach in the Greco-Roman world led to the systematization of the "roots" or "elements" described by Empedocles in the 5th century BCE: the now-iconic quartet of earth, air, fire and water. This idea and others, like the atomism of Democritus, spoke of a theoretical basis that gradually became dissociated from religious and mythological traditions. The centrality of chemical processes to humanity's use of the physical world was only dimly apparent to the thinkers of antiquity.

Chapter 2, Practice and Experiment: The Conquest of Matter treats of the emergence of chemistry in the practices, procedures, and classifications centering on a variety of materials: metals, ceramics, glass, colorants, colored stones, and minerals, as well as useful substances derived from animals and plants. The Egyptians carried on extensive high temperature procedures both in the Nile Valley and the Eastern Desert. They were technically advanced enough to invent a cheaper substitute for the costly import, lapis lazuli, that now goes by the name Egyptian blue, although they never left us a recipe. They also discovered bread, beer, and mordant dyeing. Mesopotamia had its specialties as well, including proficiency in the dyeing of wool using sources from insects, snails and plants; mineral dyes such as copper acetate were confined to the coloring of leather. But the crowning Mesopotamian chemical achievement dated to the late-third millennium BCE was the discovery of glass, described as "the first man-made translucent solid." Technical workers of the Greco-Roman world learned how to use glass to imitate gemstones, constructing a bridge between craft and nature; they also succeeded in producing a glass "stronger than metals." Their virtuosity extended to many other areas of the chemical arts that eventually produced a unified view of the nature and properties of matter.

Chapter 3, Laboratories and Technology: From Temples to Workshops: Sites of Chemistry in Ancient Civilizations. By administratively centralizing public works, exploitation of natural resources, and all manufacturing sectors, the ancient Egyptians were able to build an industrialized, food-secure economy associated largely within the broad area of religious ritual and temple practice. Indeed, as early as the fourth millennium BCE, the entire Fertile Crescent extending into the innermost reaches of Mesopotamia seem to have achieved a state-run large-scale economy of specialties wherein purpose-built or purpose-modified workplaces evolved. However, no term for "laboratory," as such, has been

discerned in ancient documents, although specific words for specialty workshops devoted to a variety of chemical arts appeared. Clever procedures accompanied by even more clever pieces of apparatus designed to accomplish sophisticated techniques began to abound. Remarkable was the description of a 4th millennium BCE apparatus consisting of a clay vessel enclosing a cylindrical sheet of copper and an iron rod. Did this device predate the accepted date of discovery of the Galvanic cell by several thousand years?

Chapter 4, Culture and Science: Gods, Myths and Religions. To the ancient, the fundamental origin and nature of matter belonged to the gods who, seemingly, were uncreated themselves. This theme runs through each of the three cultures under consideration, but with some differences. Egyptian gods operated out of a specialized context shrouded in mystery and privilege. Some of their most important “discoveries,” for example, Egyptian blue, bread and beer, remained forever secret. The Mesopotamians developed a mythological model that accounted for the efficacy of certain medicines, associated a specific goddess for each domestic technology, and later expanded this practice to other spheres of technical practice. In the Greco-Roman world, by the 5th century BCE, philosophers began to question the divine origin of the technical arts, leading eventually to attempts at explaining natural phenomena in other terms.

Chapter 5, Society and Environment: The Alteration of the Ancient Landscape. The single astounding take-away from this chapter is that all three ancient civilizations discussed—Egyptian, Mesopotamian, and Greco-Roman—mirrored in antiquity a major problem that faces our own: an overriding need for energy and the negative consequences of its unbridled consumption. Technological industrialization, in particular of metallurgy, ceramics and glassmaking, devoured massive amounts of wood, necessarily imported to treeless Egypt and Mesopotamia, leading to massive devastation of a difficultly renewable resource: the forests of surrounding areas like Etruria, Anatolia and the Iranian plateau. Coupled with the unsustainable terrestrial and atmospheric pollution left in technology’s wake, it seems like the ancient world was not a pleasant place to live in. The significantly higher lead and copper concentrations during this era are documented by analysis of Greenland ice cores. If breathing was hazardous, so was eating! Flour often contained silica fragments from the milling process leading to dental abrasion by the mere act of eating bread! Dental attrition was not limited to the lower classes but even observed among those of the ruling class. But perhaps

worst of all: dominant civilizations obtained nearly all of their mineral, animal and vegetable resources from subjugated peoples by plunder.

Chapter 6, Trade and Industry: The Circulation of Trade in the Mediterranean. Trade in Egypt centered, as might be expected, around the Nile delta with different entry points depending on the origin of the cargo. As Egypt had very little by way of natural resources except for natron, alum and other alluvial commodities, its economy relied on imports, but mostly as tribute from conquered territories. The kingdom compensated for its lack of natural resources in another way that we see imitated today: exportable development of technological expertise. Mesopotamia, on the other hand, relied on its own internal waterways for its trade, which was the backbone of its economy. It was in this atmosphere that the merchant class arose, participants in possibly the first recorded venture capital system. The Greco-Roman world saw the development of a wide array of retail shops selling goods that could be labeled “chemical,” including exotic pigments. There is a story about the Greek painter Cydias who exploited a chemical change: when a fire broke out in one of these shops, he noticed that the red ochre burned, turning purple. He used this newly discovered purple, a highly coveted hue, to paint a picture of the Argonauts that he sold for 144,000 sesterces, equivalent to the annual wage of 130 day laborers.

Chapter 7, Learning and Institutions: The Invention of Chemical Recipes. Ancient recipes prefigured the modern laboratory manual, although sometimes the directions and some of the ingredients were obscure. This deliberate obfuscation, at least on the part of the Egyptians, was to secure the control of the religious authorities over what were considered sacred texts to give them added prestige. There is speculation that these texts were read to the workers as memory aids. Step-by-step recipes emerge in Mesopotamia in the Old Babylonian Period (ca. 1800-1500 BCE) for mathematics, cooking and medical prescriptions. The recipes for glassmaking and perfumery have been recognized as the quintessential precursors for the history of chemistry. The section on the Greco-Roman world concentrates on the transmission of knowledge via apprenticeships.

Chapter 8, Art and Representation: The Iconographic Imprinting of Ancient Chemical Arts. Egyptian tombs are replete with images that depict chemical processes, but without the detail that would “give away” the secret or allow the crafty reader to reproduce the process. Mesopotamian “imagery,” on the other hand, bypasses the strictly iconographical for the metaphorical often

expressed in poetic texts as opposed to illustrations. This method allows for the use of the same word to mean different objects in different contexts, but always related to the same basic concept. For example, the metaphor for “oven” can also stand in for “womb.” The Greeks and Romans have left us copious detailed images of practitioners of the chemical arts in fresco paintings and on pottery. Representations include blacksmiths, potters, fullers, perfumers and various types of metalworkers, sometimes in mythological contexts and sometimes in actual chemical workshops.

Some general comments. One thing to note is that for each essay, the authors do not seem to feel that it is necessary to give the reader a beginning, a middle and an end. Often an essay plunges right into the subject matter *sans* context, and after a lengthy disquisition in which each item is given equal importance, comes to an abrupt end. This may be the product of the volume’s structure. Also, this reviewer would have been helped if dates had accompanied some major protagonists or commentators such as Maria the Jewess (e.g. ~1st-3rd C. CE) and Zosimos of Panopolis (e.g. 3rd-4th C. CE). Also, the chapter figures all carried informative captions but sometimes they were not called out in the text. The careful reader might be nonplussed by the substitution of “tenants” for “tenets” (p 27), “goodness” for “goddess” (p 32), “dying” for “dyeing” (pp 69 and 160), and a few more—strange typos or quirky spellcheck artifacts?

Overall this volume is a unique, comprehensive and rich treatise that encompasses thousands of years and a vast geographical swath of civilizations. It deals in detail with an all-encompassing latent chemistry that touched every aspect of human life. It is replete with references (over 50 pages) and contains a detailed and helpful index.

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Vol 2: *A Cultural History of Chemistry in the Middle Ages*, Charles Burnett and Sébastien Moureau, Eds., xiii+221 pp

A Cultural History of Chemistry in the Middle Ages, is a small but ambitious volume in this large and ambitious series. It succeeded in giving an orientation to the occult science of alchemy to this novice. I feel the need to add a disclaimer here. The review for this volume is written not by a scholar in the period but by a tyro. It contains no expert insights, but rather an account of what a chemist knowledgeable about some aspects of the discipline’s later history can make of the volume as a first step in learning about medieval alchemy.

The Introduction by Sébastien Moureau, one of the volume’s editors, provides an excellent overview both of the scope of the book and of the history of alchemy in the Middle Ages. What medieval natural philosophers called *chimia* or *alchimia*—the terms were synonymous—was “the science of matter, its composition and changes,” including some changes (such as phase changes) a modern scientist would classify as physical. For the most part, the history of chemistry in the Middle Ages is the history of alchemy and the history of chemical crafts; this volume emphasizes the former, but does not neglect the latter.

Moureau explains that during this period, alchemy was pursued in the Islamic world and in Latin Europe. (Islamicate refers to cultures in which Muslims predominate, avoiding the identification of such cultures with a single language (e.g., Arabic), ethnic group (e.g., Arab) or religion (e.g., Islamic).) This volume is the first attempt at presenting an overview of alchemy in both the Islamicate and Latin worlds. Indeed, many of the chapters are co-written by scholars expert in each of those civilizations. Moureau’s introduction describes the periods into which scholars of alchemy usually divide the study of the field: Egyptian and Hellenic, Arabic, and Latin. The scope of this volume spans these periods, including some work of late antiquity (Byzantine alchemy), of the medieval Islamicate, and of early Latin alchemy (before Paracelsus). One suspects that this scope was imposed, at least in part, by the periodization of the wider Bloomsbury Cultural History series. Whatever its origin, the resulting text emphasizes the transmission of alchemical ideas and traditions from Byzantine to Islamicate and later from Islamicate to Latin writers and practitioners.

Transmission is particularly emphasized in the first chapter (theory and concepts), subtitled “The Shared Heritage of Byzantine, Arabo-Muslim, and Latin Alchemy,” by Matteo Martelli, Moureau, and Jennifer Rampling. Transmission took place via translations as well as by pseudotranslations—works falsely attributed to a prestigious figure. Two very broad theoretical topics are treated in this chapter, namely the composition and classification of matter, as well as two more specific ones, transmutation of metals and the quintessence.

The next two chapters are co-authored by Moureau and Nicolas Thomas, and they describe alchemical operations and apparatus, respectively. The processes and equipment of alchemy have considerable overlap with those used in chemical crafts. What distinguishes alchemy from industry is theory; their operations were often similar and their tools even more so. Alchemical operations were performed on a body (base metal), spirit (often mercury) and soul (elixir)—the theoretical framework is evident in the terminology—whereas craft operations were carried out to make a useful product. Some operations described here are still used in chemistry, such as distillation—or at least distillation *per ascensum*, in which vapors rise from a liquid heated in a cucurbit to be condensed on an alembic and collected. There was also a less common distillation *per decensum*, in which solid plant matter was heated in a perforated vessel set atop another vessel which collected liquids that separated from the heated material. Others do not correspond to any single modern chemical operation; ceration (literally to make waxy) is an example. Some alchemical manuscripts contain informative diagrams of alchemical apparatus. But some of the most striking depictions of alchemy and alchemists, such as paintings by Pieter Brueghel the Elder and David Teniers the Younger, are anachronistic.

Some of the same processes mentioned in chapter 2 are also treated in chapter 6, on chemical crafts and technology, written by Justine Bayley with Spike Bucklow. Many of the technologies discussed were known in antiquity; there was little incentive to change processes once a practical one was found. The chapter focuses on two inorganic products, metals and glass. Medieval craftsmen made few innovations in metalworking, but several in glassmaking.

Chapter 4, written by Regula Forster and Jean-Marc Mandosio with Antoine Calvet and Gabriele Ferrario, examines attitudes toward alchemy by contemporary scholars. In the Islamic world, it was classified as a foreign science. Some religious scholars defended alchemy and others criticized it. There seems to have

been more of an affinity for alchemy among Sufi and Shiite scholars than Sunnī scholars. In the Latin world, philosophers who were not alchemists regarded alchemy as a mechanical art, but its practitioners considered it a branch of natural philosophy.

Forster and Mandosio, with Calvet, also wrote chapter 7, on learning alchemy. Alchemy itself was not taught in European universities, although questions about the development of metals likely were included in some courses of natural philosophy. In the Islamic world, oral transmission was the preferred form of teaching, and it is likely that this was true for alchemy. The *madrasa* was the cultural institution of the Islamic milieu most comparable to the European university. Some alchemical manuscripts seem to have been read in some *madrasas*, probably for philosophical content, but it is unlikely that any had an alchemical laboratory.

Chapter 5, written by co-editor Charles Burnett with Calvet and Bayley, examines the place of alchemy in society. That position was highly variable: the notion of alchemy as a “culmination of intellectual study” could be found in both Islamic and Latin contexts, but so could opinions that alchemists were charlatans or deluded. In the Islamic world, alchemy was associated with royalty from its origins, as tradition attributed its first text to prince Khālid b. Yazīd. In Christian Europe, several religious orders prohibited the practice of alchemy within the order. Pope John XXII condemned alchemists who did not deliver what they promised, so what the religious legal system denounced was fraud, not alchemy itself.

The final chapter, by Rampling, treats images in alchemical manuscripts from simple diagrams found in the margins to elaborate allegorical tableaux. About the latter, Rampling writes, “One of the most distinctive and remarkable features of European alchemical imagery is its fusion of Arabic alchemical tropes with Christian iconography.” The images discussed in this chapter all accompany texts, but the images and texts do not necessarily illustrate each other. The images are reproduced in greyscale in the print book but in color in the ebook.

For an alchemical tyro, this book succeeds in presenting an overview of the subject as well as numerous references to more detailed information. It provides an overview of many of the most important names in medieval alchemy as well as frequent reminders that many of those names must not be taken at face value. Pseudepigraphy (the attribution of texts to people who did not write them) pervades medieval alchemy. Many such texts were attributed to writers who had little interest

in alchemy or opposed it. Other texts purporting to be from the Middle Ages were written later, and some were attributed to fictional authors.

In addition to instructing novices, I suspect that the book will also serve scholars of alchemy as syntheses and sources of references in much the same way as scientific review articles assist both experts and beginners.

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Vol 3: *A Cultural History of Chemistry in the Early Modern Age*, Bruce T. Moran, Ed., xiii+275 pp

What is chemistry? Where did it belong? With these questions, editor Bruce Moran opens his splendid introduction to *The Early Modern Age*, the third volume in Bloomsbury's *Cultural History of Chemistry*. The same questions provide a constant refrain throughout the volume. While the eight individual chapters cover a host of chemical applications—from transmutational alchemy to mining, gunpowder-making to medicinal distillation—the fundamental problem of defining early modern “chemistry” remains at the fore of each. After all, as Moran notes, “the experience of what gets lumped together as chymistry was never one experience, and never reflected a unified structure of meaning” (p 9).

This range of experiences is both examined and embodied by a highly-qualified assembly of contributing authors, who include, besides tenured and emeritus professors, early career researchers, independent scholars, and museum and library curators. These authors bring multiple perspectives to bear on their subject, including the intellectual history of alchemy, art history, history of the book, institutional history, and the social history of secrets. Despite a few nods to the Atlantic world (notably in Donna Bilak's chapter on “Laboratories and Technology”), this is nonetheless a history that focuses overwhelmingly on the European experience, with Europe providing the stage on which the modern, Western discipline of academic chemistry gradually arose from a tangle of ideas and practices that historians are still attempting to unsnarl.

Chemistry in sixteenth- and seventeenth-century Europe—the scope of this volume—had not yet crystallized as a discipline, posing terminological difficulties both for early modern Europeans and present-day scholars. One solution has been to adopt “chymistry” (a term championed by William Newman and Lawrence Principe in an oft-quoted article) as an umbrella term for the pre-modern

chemical sciences, intended to avoid the anachronistic separation of “alchemy” from “chemistry.” Scholars of recipes, secrets, and artisanal knowledge have argued for adopting even broader definitions to represent the full range of arts and techniques in which chemical knowledge is implicated. Chemistry's borders with medicine and pharmacy were also highly permeable—but not all medicine was chemical, and not all chemical medicine was “alchemical.” Given the profusion and imprecision of available terminology, it hardly surprising that six out of the eight chapters in *The Early Modern Age* devote space to such complications. Definitional questions are important, and newcomers to the subject will certainly be left in no doubt of their ongoing importance. At times, however, I found myself skipping over passages that reprised issues already presented clearly and well in Moran's introduction.

A more engaging method for slicing and dicing chemical culture is supplied by the chapter titles themselves. These eight general headings, consistent across all six volumes in the series, invite readers to examine the topic from different vantage points. As these studies show, chemistry's place in European culture indeed looks very different depending on whether we view it as technology, economic enterprise, experimental philosophy, or literary genre. Its protagonists also change across cultural outlets—so, in some chapters we meet physicians and university-educated scholars; in others, painters, craftsmen, and charlatans. Women make walk-on appearances, especially in craft contexts, although the few to be mentioned by name (Martine de Bertereau, Margaret Cavendish) hail from the upper classes.

All of the contributors to this volume provide solid surveys of their designated topics, although the fixed chapter titles are still not quite enough on their own to corral chemistry's sprawling and invasive character. There is, for instance, considerable topical overlap between William Eamon's chapter on “Society and Environment” and Tillmann Taape's on “Trade and Industry,” each of which includes sections on print, secrets, and women distillers. On the other hand, such duplications do allow contributions to function as freestanding units—a feature that doubtless accords well with Bloomsbury's strategy of making chapters available for individual download for subscribers to the online “Cultural History” database. Read on its own terms, Eamon's chapter makes a strong case for the diversity of chemical practices within a bustling marketplace of craft knowledge, medical secrets, and printed books—the contexts in which most early modern people would have experienced “chemis-

try” first hand. In an undergraduate syllabus, it would pair well with Margaret Garber’s valuable survey of “Learning and Institutions,” with its lucid case studies of major sites of courtly patronage and university learning, as a combined introduction to the places and spaces of chemical knowledge. Taape’s chapter, too, stands well on its own, offering a rich and highly-teachable account of early modern cultures of distillation, a topic on which he is a subject specialist. Andrew Sparling uses the itinerant career of Paracelsus, the focus of his own compelling dissertation, to illustrate the mutability of chemical sites and identities in “Culture and Science.” And Joel Klein’s fine chapter on “Practice and Experiment” breaks down a potentially overwhelming topic by focusing on techniques of analysis and synthesis, while clearly showing how experimental results worked to advance chemical theory (a topic treated separately in Lawrence Principe’s jam-packed chapter on “Theory and Concepts”).

The volume is at its best at moments like these, when the contributors’ own expertise shines through the generalities of the survey format, imbuing the subject with human warmth. Even so, the job of supplying introductory coverage means that most chapters tend towards the summary of existing knowledge rather than fresh argument. A welcome exception comes partway through Elizabeth Drago’s chapter on “Art and Representation.” There, Drago claims that a scholarly emphasis on famous depictions of fraud—including the ubiquitous engraving of Peter Bruegel the Elder’s “The Alchemist”—has distracted attention from other, less stereotypically critical studies of alchemical practitioners, including “wittily painted” representations of laboratory equipment (p 224; a genre that Bilak also discusses). It is telling that Drago is one of the only authors who elects not to intervene in the terminological debate that sucks up some of the argumentative oxygen in other contributions—thereby gifting herself the space to tell another story. This volume will be valuable to readers both in whole and in part, but a few more adventurous pushes like this might have jumpstarted the book from usefulness to indispensability.

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Vol 4: *A Cultural History of Chemistry in the Eighteenth Century*, Matthew Daniel Eddy and Ursula Klein, Eds., xi+238 pp

The fourth volume in the set, this collection of essays focuses on the period between 1700 and 1815, questioning and re-assessing the narrative concerning changes and

shifts at the center of the so-called Chemical Revolution, and discussing related matters according to the relevant cultural context.

Besides a clear and compelling introduction by the editors (pp 1-21) discussing how, during the eighteenth century, chemistry expanded from being an art and a philosophy practiced in a variety of contexts into a fully institutionalized discipline, the collection includes—like the other volumes in the set—eight themed chapters dedicated to Theory and Concepts, Practice and Experiment, Sites and Technology, Culture and Knowledge, Society and Environment, Trade and Industry, Learning and Institutions, Art and Representation.

After the first chapter, by Ursula Klein (pp 23-44), devoted to a succinct yet accurate survey of the salient moments that characterized the transition from speculative philosophies of matter to quantified chemistry during the eighteenth century, chapters 2, 3 and 6, by Victor D. Boantza, Marco Beretta and Leslie Tomory, respectively (pp 45-91, 137-156), dealing with more practical and technological issues, can be read as a whole.

Chapter 2, while consolidating the generally accepted interpretation according to which in pre-Lavoisierian chemistry experimental practice changed more gradually than theoretical developments, clearly illustrates how Lavoisier’s theoretical and instrumental novelties built on the unprecedented investigative efforts that characterize the history of eighteenth-century chemistry.

Chapter 3 deepens the analysis of related topics, discussing how the exponential increase in discoveries in chemistry during the eighteenth century was the result, not so much of new theoretical ideas as of the increasing accuracy of analytical methodologies and apparatus. Such growth reached a turning point with the work of Lavoisier, whose methods would be adopted by French institutionalized chemical research already in 1795.

Chapter 6 illustrates instead how, during the century in question, traditional trades developed into full-fledged chemical industries, with particular emphasis on textile production, mining and metallurgy, domestic goods, potash, soda and gunpowder.

In a work substantially designed to be a handbook as updated as possible, chapter 4, by Bernadette Bensaude-Vincent (pp 93-112), is crucial, as it illustrates the state of the art in the perception of the history of chemistry in the eighteenth century by drawing parallels between modern-day scholars and those who made such history. Moreover, this chapter represents a necessary and spot-on

methodological counterbalance to other chapters, such as those just mentioned, devoted to aspects more pertaining to the field of the history of technology. Bensaude-Vincent in fact shows the obsolescence of the depiction of eighteenth-century chemistry (prevalent until a few years ago) as the age of waiting for the coming of Lavoisier, building instead on the discussion concerning how the characters in this story were inclined to frame chemistry as a discipline living its golden age within the boundaries of Enlightenment. Both methodological and practical aspects are emphasized, from the increasing linkages between reasoning and experiment as a key feature of modern chemistry up to the establishment of connections put forward by chemists between natural knowledge and power over the material world in the perspective of social advancement, technological implementation, and industrial development. Thus, chemistry—already before Lavoisier—was emerging as a multi-faceted “science intimately connected to daily life, moreover in the service of public welfare and a strategic asset for the prosperity of nations, appear[ing] as a glamorous endeavor for all educated persons” (p 112).

Chapter 5, by Matthew Daniel Eddy (pp 113-135), addresses the growing awareness—demonstrated by eighteenth-century men of science—of the possibility of technological, industrial and economic exploitation of processes and cycles of the material world. Related topics are discussed through a case study dedicated to the short-lived but influential Baptist’s Head Coffee House Philosophical Society, active in London between 1780 and 1787, the members of which included prominent experimentalists of the period, such as Ami Argand (1750-1803), Richard Kirwan (1733-1812) and Joseph Priestley (1733-1804).

Chapter 7, by John C. Powers (pp 157-174), deals with the exponential progression in the institutionalization of chemical education, representing the ideal complement to many of the topics discussed and hinted at in the chapter by Bensaude-Vincent. Powers illustrates how, in the heyday of Lavoisier’s reform, a varied academic formal context for the teaching of chemical knowledge already emerged in a number of European countries. Thus, contributing to the tradition of historical studies inaugurated in the 1980s by Frederic L. Holmes and brought forward by scholars such as Jan Golinski and Mi Gyung Kim, the chapter emphasizes how research concerning the history of eighteenth-century chemistry should not be approached as the foreground to Lavoisier, but through a proper contextualization of primary sources.

Chapter 8, by John R. R. Christie (pp 175-202), contributes to showing how vibrant and manifold chemistry was and was perceived as it discusses the artistic representation of chemistry and its protagonists during the century at issue. Such representations (p 202)

include attempts by chemists to promote positive public images of a progressive science; they range from canonical painting to popular caricature, from domestic poetry to canonical novel [...]. They develop senses of chemistry’s immediate and longer-term historicity as they become engaged in Gothic revivalism, in formal historiography, or in the contemporary history of the Chemical Revolution and the French Revolution

Designed as both a study companion and an updated reference work, this book accomplishes the stated goals, being an excellent complement for students as much as an enjoyable reading for those interested in the history of chemistry and the history of science in general. Nevertheless, considering the proclaimed (and largely honored) adoption of a cultural history approach, the only discernible flaw is represented by the absence of sections dedicated to history of alchemy and philosophy of chemistry, sparingly (even if properly) addressed only on a few occasions (pp 98, 108-112, 171-173, 183-185).

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Vol 5: *A Cultural History of Chemistry in the Nineteenth Century*, Peter J. Ramberg, Ed., xiii+272 pp

The fifth volume of *A Cultural History of Chemistry* covers the long nineteenth century, generally from Lavoisier up to the eve of World War I. The Introduction (pp 1-39), titled “Creating Modern Chemistry,” essentially serves as a summary of the entire volume. As Peter J. Ramberg states, during this period chemistry saw “explosive growth ... as a science, as a profession, and as an industry” (p 2). This period was characterized by the unification of chemistry as a scientific discipline as well as the creation of social and cultural structures within which chemists practiced their discipline in academia and in industry. This is shown in sections on atomism, organic chemistry, the development of a general chemistry, pedagogy, the professionalization of chemistry, national styles and internationalism, the chemical industry, and radioactivity.

The theme of chapter 1 is Theory and Concepts, with a focus on “Atomism, Structure, and Affinity” (pp 41-65).

In this chapter Trevor Levere discusses four major themes of chemistry during the nineteenth century: atomic theory and atomic weights, the structure of atoms in molecules, the reformulation of chemical affinity into chemical thermodynamics, and developing laws that pertain to all areas of chemistry. As Levere notes, none of these themes “can be fully separated, because they often informed one another” (p 42). In many ways this is the most theoretical of the chapters, but it nonetheless touches on many of the social and cultural themes of the volume.

Practice and Experiment are the theme of Chapter 2, titled “Analysis, Synthesis, and Paper Tools” (pp 67-90). Yoshiyuki Kikuchi seeks to answer the question “what exactly did the act of experimentation entail in nineteenth-century chemistry?” (p 67). The practice of chemistry shifted from an emphasis on collection, description, and classification to that of analysis and synthesis. Laboratory equipment and conditions are discussed, but much of the chapter is concerned with the use of paper tools, three-dimensional molecular models, and the hypothetico-deductive method. The impact of physical chemistry is also discussed, particularly the increased use of mathematical and physical methods.

The discussion of theoretical and paper tools in Chapter 2 flows neatly into Chapter 3, the theme of which is Laboratories and Technology (pp 91-115). In “Continuity and Ingenuity in the Workplace,” Amy A. Fisher examines changes in chemical standards, instrumentation, and laboratory design and construction. The transition from laboratories as “places for making things” (p 93) to “matter factories” which produced knowledge as well as things (p 92) is the focus of the first section, primarily the development and growth of laboratories in educational settings. One of the major changes that took place in laboratories was the ability to connect to water, electric, and sewer lines which not only made labs safer but also inspired new tools such as Bunsen’s burner. The section on chemical apparatuses illustrates the continuity of methods and the development of new equipment that deepened the understanding of composition and structure that lies at the heart of chemistry.

Chapter 4 is concerned with Culture and Science (pp 117-137). “Chemistry Spreads Its Influence” shows the ways in which chemistry, as a professionalized discipline, exerted its influence on other scientific disciplines, in industry, and in the public imagination. As Augustí Nieto-Galan and Peter J. Ramberg explain, the nineteenth century provided “the foundations for this central nature of chemistry” (p 118). Theory and practice, as well as pedagogy and consumption, provided the means for

chemists and chemistry to forge connections with biology and medicine, physics and astronomy, theology and ideology, industry, and the public sphere, thereby spreading its influence both within and outside of science. The chapter is in some ways a preview of the topics that are discussed in more detail in Chapters 5, 6, and 7.

The theme of Society and Environment is the focus of chapter 5, which is concerned with “Increased Access for Women, Growing Consumerism, and Emerging Regulation” (pp 139-166). Peter Reed looks at the ways in which chemists played a wider role in industrialized societies through advances in chemical analysis and the modification of chemical processes from trade craft to forms more suited to factory settings, such as those used in dyes and soap-making. The engagement of women in chemistry is discussed from the self-taught women who wrote popular works to those that benefitted from changes in educational standards and were able to take on roles as laboratory assistants, educators, and professional chemists. Another focus is the role of chemistry in making improvements to medicine and to everyday life, often at the expense of the environment, which also served to open new avenues for analytical chemists.

Chapter 6, with the theme of Trade and Industry, is in many ways a continuation of the previous chapter, focusing as it does on “New Demands, New Processes, and the Emergence of Science-Based Chemical Industry” (pp 167-190). Anthony S. Travis shows how chemical industries became “central to the interplay of demand and change” that allowed for the development of an economically dynamic Europe. Likewise, by about 1870, these industries “assumed national importance” (p 168). As noted in the previous chapter, craft-based skills gave way to theory-driven chemistry. The resulting products included synthetic dyes, soap and glass, pharmaceuticals, fertilizers, pulp and paper, food additives, and explosives. These were the result of new methods of production, including the development of synthetic products used as substitutes for natural ones and the creation of completely new substances.

The next chapter provides more detail on some areas that are mentioned in previous chapters. The theme of Chapter 7 is Learning and Institutions (pp 191-215). In “Emergence of Laboratory-Based Learning, Research Schools, and Professionalization,” Peter Reed looks at the role of local cultural institutions, such as mechanics’ institutes and the Royal Institution, in spreading chemistry through educational initiatives in non-traditional settings. Also discussed is the introduction of science in general, and chemistry in particular, into secondary schools in the

second half of the nineteenth century. Likewise chemical instruction in colleges and universities increased over the course of the century, incorporating hands-on laboratory work with the more traditional lectures. Research schools began to rise around individual professors. As chemists began to specialize (e.g., organic chemists, analytical chemists), the professionalization of chemistry increased. General organizations such as the British Association for the Advancement of Science and the American Chemical Society brought chemists of all kinds together, but there was also a proliferation of smaller and more specialized groups which also published their own journals.

Chapter 8, the final chapter of the volume, takes a very different look at chemistry as it is devoted to the theme of Art and Representation, particularly “The Rise of the ‘Mad Scientist’” (pp 217-238). Joachim Schummer devotes most of the chapter to the representation of chemists and chemistry in literary works. He begins with a history of the “mad alchemist” trope that was popular from the fourteenth century through the eighteenth century. He then looks at various types of the “mad scientist” beginning with *Frankenstein*. Perhaps the most interesting is Sherlock Holmes as an example of the heroic crime investigator, a type of “mad scientist” which acknowledges eccentricity as being a “useful way of reasoning, rather than condemning it as a form of madness” (p 230). The chapter concludes with a brief discussion of visual representations of chemistry and chemists, which during the nineteenth century were largely commissioned by chemists themselves and did not make a great impact on the public imagination.

Perhaps unsurprisingly, several themes are touched on in most of the chapters. One is the national character of chemistry and its importance in the larger national identity. At the same time, there is an acknowledgment that international cooperation was important for the advancement of chemistry as a science. Another theme is the rise of organic chemistry and the development of other specialties such as physical chemistry and analytical chemistry. Despite the proliferation of specialties, there was also a trend towards the creation of a general chemistry not only for basic education but also for agreement on chemical laws and standards which were applicable to all areas of chemistry. Finally, the importance of chemistry to the industrialization of the world is readily apparent. Chemistry contributed to the development of new processes and new products, as well as to damage to the environment.

Each chapter of this fifth volume of *A Cultural History of Chemistry* provides an overview of a specific

aspect of chemistry during the long nineteenth century. For those that want to take a deeper dive into an area, the chapters provide a good starting point, with a good bibliography from which to move forward. While some of the material covered was not new to me, I nonetheless learned quite a bit. I particularly enjoyed the chapter on the “mad scientist” trope. The discussion of *Frankenstein* provided details I was unfamiliar with despite having read and discussed the novel multiple times in various courses over the years. Overall, this is a welcome addition to the literature on chemistry in the nineteenth century.

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Vol 6: *A Cultural History of Chemistry in the Modern Age*, Peter J. T. Morris, Ed., xiv+281 pp

The Bloomsbury *Cultural History of Chemistry* is part of an established series of volumes spanning over a hundred topics to date, from Furniture to Genocide, and all around. Six hundred bucks will get you six volumes on each topic. The gaping hole of science in this remarkably broad survey of human culture is being filled by a set of volumes on chemistry, chronologically arrayed; I am asked here to tell you of the volume on the modern period, here defined as the past century, from World War I on.

I have been active as a chemist for just about half of that period. And I have an abiding concern about “chemistry in culture, and culture in chemistry.” So one would expect I would be an ideal reviewer. But perhaps not, for I have participated so intimately in some of the scientific developments surveyed, that it is difficult to step back and take the balanced perspective on what one was in the midst of. It’s not quite a good analogy, but those of us who were busy surviving in Poland in 1943, had no idea of what was going on in North African fighting in the same year. But let me try to outline the contents of this valuable volume.

Beginning this volume, Mary Joe Nye is an ideal reporter for the “Theory and Concepts” section (the Bloomsbury Cultural History format dictates a leitmotif for each chapter. Which the authors follow or subvert...). She follows well the interesting way in which the chemical bond resisted the quantum mechanical ways to question its existence. And how Lewis, Ingold, and Robinson intuited the quantum mechanical expression of bonding that Pauling and Mulliken and others made clear. As Nye says “...complementarity of mechanisms and representations are natural to chemistry and not at all concessions of failure.”

In a chapter on “Practice and Experiment,” José R. Bertomeu-Sánchez and Antonio García-Belmar write of a range of practices, from the instruments of the chemist to what they are taught. They have a very nice account of the role of molecular models, with the insight that “... molecular models have defined and redefined, rather than represented, molecules.”

Peter Morris, one of the editors of the entire series, writes with expertise of the chemical laboratory in this century, both as it changed and didn't. His account is especially good on sketching how different the nuclear magnetic resonance, nmr, machines were to chemists, both in their manufacture (no optical components in them), and in their use. He notes the 8,000 copies sold, at a relatively high price, of Jack Roberts's *Nuclear Magnetic Resonance*. Morris also has an excellent account of the development of chromatographies in the period covered. These methods, unlike nmr or infrared and UV spectroscopies, did not have the benefit of romantic connections to state-of-the art physics. Nor were there explanations for separation phenomena based on molecular orbitals or rate constants for simple reactions. Not that organic chemists (and biochemists, and industrial chemists) failed to value and use these techniques.

In an insightful article, Carsten Reinhardt begins by seeing chemistry at the beginning of the period as providing in abundance the makings of modern society “between Ersatz and miracle.” But even as the physicist's war (which should have been called the chemist's war) was over, as chemical industry was being rebuilt or flourishing, and support for chemistry abundant, our field enters a crisis of confidence. The loss of the centrality of chemistry is traced, in a careful reading by the author, in two major contemporary reports on the state of the science. The future is (perhaps) “outside of chemistry.”

The shift from a romantic view of chemistry as the heroic enabler of a better life, to real concern about what the abundance of cheap synthetic materials does to the air, waters, and soils of the planet and to our bodies, is succinctly traced by Peter Reed. He also provides an analysis of the growth of the participation of women in the chemical profession.

Peter Morris and Anthony Travis are the right people to analyze, in a chapter on “Trade and Industry,” the growth and profound changes that the century brought to chemical industry. They discuss carefully the ingenuity marshalled coping in two wars, the important role of the growth of the automobile industry for chemicals, and the

transformative nature of plastics. They detail how, despite expectations that the chemical industries would continue a march ahead (even if IG Farben was broken up), other factors led to large-scale rearrangements and crisis post World-War II. The raw material changes, petrochemistry and requisite oil resources mattered more. And a resurgent Japanese industry (and now that of China), along with a multitude of takeovers and spinoffs created an entirely new landscape across commodity chemicals, pharmaceuticals and materials. It's an uncertain, precarious and exciting world.

I would have wished a little more, if not here than in another chapter, on the role of chemists-inventors, on start-up companies, and the growing (or diminished) role of chemistry in the trillion dollar companies of the IT age.

Jeffrey Johnson, Yasu Furukawa and Lijing Jiang give us a welcome broad view of “Learning and Institutions.” The scope is appropriately global and well documented. It is especially good in detailing the growth of the Japanese research enterprise in the 20th century, and the exponential growth of Chinese science.

In the final chapter of the book, on “Art and Representation,” Joachim Schummer gives us a perceptive and extensive analysis of the main tropes in which chemistry was perceived by the general public in the 20th century. He shows in detail how the old “mad scientist” caricature evolved into superheroes and supervillains, with chemistry figuring importantly in the existence and actions of both. Maybe more so for the bad guys. Interestingly, children were more likely to be fed another stereotype—the absent-minded professor. Schummer describes the fascinating growth of the chemical content of apocalyptic narratives. And he shows how standard plotlines in the chemical industry's imagined (but based on authentic events) causation and resistance to remediation evolved. He makes the important—and disheartening—observation that once the theme of an environmental apocalypse entered our imagination “...chemistry, much more so than any other science or technology, became firmly associated with the total destruction of the world as we know it.”

I may think of myself as a reflective observer as well as long practitioner of chemistry, but reading the *In the Modern Age* volume of this series made me aware of how limited in fact my perspective was. The information on the growth, diversification and fragmentation of chemical industry in the 20th century was very informative. To go back to the analogy I gave at the beginning of this review, of the ignorance due to being in the midst of a

war, I chose, out of intellectual laziness or compartmentalization, not to know of these gigantic transformations. Even as my students were looking for jobs in just these companies. Not good. But not too late to learn about this, or to learn of the German or French novels that

made us imagine a chemical apocalypse. This volume of *A Cultural History of Chemistry* was educational, and fun to read.

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March of the Pigments; Color History, Science and Impact, Mary Virginia Orna, Royal Society of Chemistry, 2022, 477 pp. Print ISBN: 978-1-83916-315-9 £34.99, EPUB ISBN: 978-1-83916-326-5.

Color is a powerful communication tool and can be used to signal action, alter mood, and even influence physiological reactions. Psychologists have established that different colors are perceived to mean different things. For example, tones of red lead to feelings of arousal while blue tones are often associated with feelings of relaxation. The psychologist Carl Jung is quoted for saying, “colors are the mother tongue of the subconscious.” Color has always been recognized for its symbolic power, and thus has always played a key role in the process of artistic expression.

There is a prodigious amount of literature on the theory of human color perception and aesthetics. Equally voluminous is the literature on humanity’s efforts to artificially recreate the various shades and hues we perceive. The geochemistry, chemistry, and manufacturing technology of various pigments has been treated in countless publications, from specialized monographs to Nicholas Eastaugh et al.’s *Pigment Compendium*, the go-to reference for art historians, object conservators and cultural heritage scientists.

Very few if any books, however, discuss color and pigments in a unified way, placing pigments in a cultural context and examining their materiality. Mary Virginia Orna’s *March of the Pigments* goes a long way towards filling that gap. This pedagogically versatile book consists of sixteen thorough, accessible and extensively researched chapters. They take the reader from the deep unrecorded past, through successive periods of history to the present, and even offer a glimpse of future pigment technology.

Following some introductory photophysics and photobiology in Chapter 1, Chapter 2 is a harbinger of delights to come. Here, Orna sets the historical stage for the rest of the book. When the curtain first rises, we find ourselves some 35,000 years ago, in the Aurignacian. Orna’s fluid prose moves effortlessly from recounting the human interest story of 8-year old María noticing the wall paintings in Altamira for the first time in 1878 to describing the complex procedures involved in selecting and preparing the pigments used by our ancestors. It is unlikely that we will ever know much about paleolithic languages. The oral transmission of these sophisticated material manipulations, however, that remained stable over extended periods of time, presupposes a rich vocabulary.

Chapter 7 uses Pompeii as a backdrop to introduce the reader to the origins of archaeological chemistry, teach us about *fresco* techniques and the properties of the pigments used in *fresco* painting. It subsequently integrates the parts to recreate the cultural and archaeological context. All along there are references to progress in archaeometric techniques, and the chapter ends with a very substantive discussion of polychromy in ancient statuary.

As Chapter 8 opens we find ourselves in the late Roman Empire, besieged by Lombards, Huns and Ostrogoths. The Dark Ages were about to break out over Europe. But while the Empire was imploding, the Irish monastic movement created islands of stability where the written heritage of Western civilization was preserved and later reintroduced to the Continent under more favorable circumstances. The tool for this was in Orna’s view the illuminated manuscript, which, echoing Thomas Cahill’s words, she sees as “...the torch that set the gloom of the Dark Ages ablaze with light again.” From there it is a short leap to modern non-destructive archaeometric

methods and a discussion of the vast diversity of colorants used in manuscript illumination as revealed by these techniques. One pigment, ultramarine, is singled out for a closer look at its social, artistic and economic impact.

In Chapter 9, Renaissance serves as the catalyst for discussing the chemistry of the vivid colorants and their binders favored by the masters, from Giotto and Botticelli to Leonardo and Titian. One sentence in the concluding paragraph sums up the overall picture very succinctly: "...the Renaissance artists depended heavily on materials that were in no way innovative but of very fine quality." The higher quality arose from the commercialization of artists' materials, with Venice becoming an important early hub of this trade and the Venetian authorities regulating the quality of the materials. In contrast, two centuries later artists working in ceramics, glass and the enameling of metals were still preparing their own pigments. That raises the question, did the medium and its traditions determine the timing of the transition from "homemade" to commercial?

An important feature of the book is its versatility as a potential source of reading material for courses at various levels, ranging from the undergraduate chemistry curriculum to special topics in cultural heritage science. Each chapter can be read and appreciated independently of the others. Chapters can therefore be used individually as assigned reading material for courses at both undergraduate and graduate levels. The book does not, nor did it ever intend to break new ground in identifying novel pigment classes, pigment structures or unsuspected

trade routes for artists' materials. But it is also a lot more than simply Eastaugh's *Pigment Compendium* in narrative form. The book's strength is in uniquely placing the material information into a broader cultural framework. It inspires the readers to raise and research their own new questions. The wealth and appropriate contextualization of factual information and the extensive list of references make this book an indispensable resource for both educators and researchers.

As a compulsive nitpicker I would be remiss not to point out a few minor errors of omission. In Chapter 4, on Egypt's legacy, a little bit more could have been added about the detection of a blue Co/Al spinel in the decoration of Hathor jars from Malqata, essentially identical to the much later Thénard's blue. The cobalt salts were extracted from the cobaltiferous alum deposits in the Dakhla and Kharga oases of the Western Desert. Similarly, Chapter 5 should have included a discussion of the cobalt mines in Erzgebirge, the politics of smalt production and the associated periodic export restrictions on cobalt ore. When discussing plasmonics in the futuristic final chapter, it would have been interesting to point out that the color of gold nanoparticles in the Purple of Cassius is indeed an example of a plasmonic effect. But these are all minor and ultimately inconsequential points that in no way detract from the value of this remarkable book.

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Science in London: A Guide to Memorials, Istvan Hargittai and Magdolna Hargittai, Springer, 281 pp, ISBN 978-3-030-62332-6, (eBook) ISBN 978-3-030-62333-3, \$54.99.

"**A Walking Tour of the City.**" Beginning in the late 1900s, a common offering for tourists visiting European cities has been "A Walking Tour." For example, in 1998 when my partner Jenny and I visited Berlin, we took advantage of "A Walking Tour of Berlin" where the guide took us on a two-hour guided tour along the famous

Under den Linden boulevard from Alexanderplatz (main transport and commercial hub, a popular starting point for tourists) to the Brandenburg Gate (the historic gateway to Berlin, where Ronald Reagan delivered his 1987 "Mr. Gorbachev, tear down this wall" speech). This 3.2 kilometer stroll took two hours, as the guide identified and discussed the important historical sites.

Continuing in this tradition, in their monumental work *Science in London*, the team of Istvan and Magdolna Hargittai have described the progress of science

in London, England, since the days of Francis Bacon (1561-1626) and Isaac Newton (1643-1727) by taking us on a virtual tour of the memorials devoted to explorers, scientists, men and women in medicine, innovators, engineers, and technologists. The contribution of each of these persons is described in detail, giving the reader a feeling of “being there” in a living history. And what a walk it is! This is a journey that would take weeks, if not months, to complete in person. Paul Nurse, Nobel laureate and former President of the Royal Society London, expressed it this way in the Foreword of the book, “Over the years, I have walked the streets of London. ... But despite my familiarity with London and the science of London, I have been astonished by what I have read in this book, what was revealed to me that I was not aware of previously.”

When one visits London, first impressions commonly include the “blue plaques” scattered about the city. In all there are almost a thousand of them throughout London; these memorials underscore the pride of the British in their understanding of the role played by London in the progress of science, arts, and politics. The “blue plaque” scheme was set up in 1866 by English Heritage. They have proved to be most popular and have been copied (sometimes with variations, e.g., “brown plaques,” “gray plaques,” etc.) throughout the British Isles, including Manchester, Oxford, Cambridge, Edinburgh, Dublin, etc. The Hargittais include photographs of these plaques in their presentation, enough in itself to fill out a travel guide. But they go much further and include photographs of important buildings, statues and other memorials, including the museums and the famous research institutions, as well as portraits of famous people. And to complete this grand tour of London, the Hargittais describe in detail the significance of each site.

My wife and I could have really used the Hargittais’ book when researching London! No such comprehensive guides were available when we explored other cities in Europe (1). For example, when trying to locate Antoine Lavoisier’s history in Paris, we reviewed the celebrated Hénocq’s *Les plaques commémoratives des rues des*

Paris and found nothing on this celebrated “Father of Modern Chemistry.” We resorted to walking the streets of northern Paris in the vicinity of the Bastille (where Lavoisier’s La Petit Arsenal laboratory was located), searching carefully, and finally after two hours stumbled on a modest plaque on the side of a municipal building. A similar experience was locating a plaque devoted to Martin Heinrich Klaproth’s (discoverer of uranium) on a wall across from a restaurant in a shopping center in Berlin, Germany, where the only guiding information we had on his laboratory location from the German Historical Society was “it was on Spandauerstrasse, close to the Nikolaikirche (St. Nicholas Church).” But now with London, readers in the comfort of their armchairs have the ability to tour London at leisure and not miss a thing.

Science in London is divided into five sections. First, the Introduction initiates the virtual traveler into the history of science in London, with description of the various museums and galleries. Second, the explorers are discussed, including the history of the British Empire. Third, the scientists are treated, including a history of the Royal Society and the Royal Institution. Fourth is the history of medicine in London, and lastly the innovators, engineers, and technologists. Frequently reference is made to other

cities, as important persons would migrate between London and other places throughout England, Scotland, Wales, and Ireland. In all over 900 scientists, explorers, engineers, and artists are included. One can leisurely “walk” through the pages and visit the Royal Institution (where Humphry Davy gave his famous lectures and Michael Faraday served as his apprentice); by the Royal Society founded by Robert Boyle, Christopher Wren, and others; the University College London (where William Ramsay discovered the inert gases); King’s College (where Rosalind Franklin performed her landmark DNA research);

scores of homes of individual scientists; the British Museum, the Natural History Museum, and the Science Museum; on and on through miles of exploration.

To illustrate the completeness of this Tour, a search was made in the book for one of the most difficult plaques



Figure 1. Joseph Priestley blue plaque in Hackney. *Science in London: A Guide to Memorials*, p 133 (image credit, Spudgun67)

during our Rediscovery research (1)—Joseph Priestley’s stay at the Gravel Pit Chapel in the Hackney borough before migrating to the United States. In our original search in 2000, Jenny and I located the blue plaque after two hours search—but in the Hargittai book, one can find it quickly (Figure 1). (The Hackney plaque, mounted on the wall of a shoe factory, is now in an alley hidden from street view and can be only be clearly seen from the window of an adjacent building.)

Science in London is not intended necessarily as a reference book (there is no subject index); one can wander through countless streets, sometimes meeting the same scientist at various locations. For convenience, an index of names can be used to find these scientists, explorers, and other notables as they moved through

their careers. Frequently a person lives in a geographical location apart from London for part of his career, and this is noted. An index for sites, however, is not included, although addresses are given for them accompanying the many illustrations.

This book is highly recommended for the lover of science—and should serve as a pleasant vicarious visit for the reader, at his leisure without the rush (and expense) of today’s travel.

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1. J. L. Marshall and V. R. Marshall, Rediscovery of the Elements, <https://www.chem.unt.edu/~jimm/REDISCOVERY%206-10-2021> (accessed Sep 6, 2022).

Wilhelm Ostwald: The Autobiography, Robert S. Jack and Fritz Scholz, Eds., Springer, Cham, Switzerland, 2017, 688+xi pp, ISBN 978-3-319-46953-9, \$147.00.

This is a long-needed English translation of the autobiography of the great German/Latvian physical chemist, Wilhelm Ostwald, originally titled in German *Lebenslinien: Ein Selbstbiographie* and published as three volumes by Kasing of Berlin in the years 1926-1927. The compression of this translation by Robert Jack of the original three German volumes into a single volume has resulted in a massive 688 page tome printed in rather small, close-spaced, type on the heavy, glossy paper favored by Springer. I can’t express enough my admiration for this wonderful translation, which has, for the first time, made this virtually untapped treasure trove of previously unexploited personal impressions of late 19th- and early 20th-century European chemistry, by one of its most important participants, available to English-speaking historians of chemistry.

The main reason for the size of the autobiography is that Ostwald spares the reader no details of his life and

opinions. We learn the names of each of his childhood friends in Riga, Latvia, and the games they played; how many of his fellow fraternity brothers at university in Dorpat (now Tartu), Estonia, died of alcoholism from too much partying; his failure during his student years to master the cello; how many vacations he took in later life and where and why; what scientific conferences he attended, what happened at each, and whom he met; what university committees he served on at Riga and Leipzig, as well as the details of the resulting arguments over curricula and funding; and last, but not least, what gifts he was given by the students each year at the annual Christmas party held in the physical chemistry laboratory in Leipzig. This might seem like mind-numbing overkill, but in fact most of it is extremely interesting. Thus we learn of the three-cornered conflict between the German community in Riga, to which Ostwald’s family belonged, and both the native Latvians and the Russian overlords that controlled the country and its school system. We learn that many aspects of both student behavior and university politics have not changed much during the past 150 years, nor has the nature of scientific meetings and the behavior of the scientists who attend them, and we

learn of the close-knit camaraderie of a late 19th-century research group.

But of even greater interest are Ostwald's impressions of the many well known late 19th-century chemists that he encountered during his career—often with surprising results. Thus, for example, when tabulating how many German universities responded to the newly developing field of physical chemistry by establishing a chair in the subject, he provides a passing observation concerning the famous German organic chemist, Adolph von Baeyer: "Munich held out the longest because there A. von Baeyer wanted no other Gods set beside himself."

Likewise, he complains that Mendeleev, because of what Ostwald calls "his serendipitous discovery" of the periodic law, had too much undeserved authority during the various debates over the theory of solutions in the 1880s and 1890s, adding that:

... what is ignored because of his great discovery is that he made no other similarly important contributions; in fact no other contribution from him has become part of the corpus of science.

Perhaps the most poignant of his encounters was with the great German historian of chemistry, Hermann Kopp:

He complained about the discomforts of getting old, especially of the loneliness that accompanies it. "Look at this," he said as we stood beside his writing desk. "It's like a graveyard. The inkwell is from Liebig, the pen is made out of the first batch of technically produced aluminum and was a gift from Deville, the medal there is from Berzelius and is made of selenium which he discovered—they are all dead."

And certainly one of the most tragic encounters involved Ostwald's friendship with William Ramsay, the discoverer of the noble gases. The two became fast friends while attending the 1890 Meeting of the British Association for the Advancement of Science in Leeds. After the meeting Ramsay invited Ostwald to spend a week with his family in Scotland, where he was given tours of the surrounding countryside and was even required to accompany the family to Sunday church services. (Ostwald was an atheist.) In subsequent years the two chemists visited one another whenever an opportunity presented itself—sometimes in England and sometimes in Germany. Though Ramsay had done graduate work under Rudolf Fittig at Tübingen and was well versed in German culture, in 1914:

Our friendship was torn apart by the World War when feelings ran high and Ramsay developed a fervid hatred for everything German. He was one of the many

victims of the lying propaganda—worse than poison gas—which our enemies used against us. Given his knowledge of German life, this inability to withstand these slanders, whose lack of truth should have been obvious to him, was perhaps due to the illness which soon led to his death.

Many years ago I read a review of a recently published book on orbital symmetry by the American chemist, Ralph Pearson, in which the reviewer characterized the book's subject matter as "Pearson's third crusade"—the first having been crystal-field theory and the second hard-soft acid-base (HSAB) theory. Similarly, Ostwald's career in chemistry can also be divided into three crusades—the first being his consolidation of physical chemistry into a recognized branch of chemistry based on the concepts of chemical equilibrium, Arrhenius' theory of ionic dissociation, van't Hoff's theory of osmotic pressure, and his own founding and editorship of the *Zeitschrift für physikalische Chemie*; the second being his attempt to displace the atomic theory with his alternative program of energetics; and the third being his work on catalysis, for which he received the 1909 Nobel Prize in Chemistry. As might be expected, each of these crusades is discussed in great detail by Ostwald, and many interesting facts are revealed that are missing from our conventional secondary accounts of these events.

Ostwald also indulges in a great deal of self-analysis. He admits that he lacked good diplomatic skills and that his aggressive enthusiasm for his various crusades often needlessly antagonized his listeners. In 1896 he suffered a major mental breakdown. This was precipitated by a combination of causes, including overwork, and the violent opposition to his first attempt to publicly present his ideas on energetics, which he encountered at the meeting of the German Society of Naturalists and Physicians, held the previous year in Lübeck, Germany. On returning to his duties at Leipzig after a lengthy recuperation, Ostwald found that, though he had recovered his ability to write and edit, he had lost his enthusiasm for working in the laboratory and, as result, his subsequent researches on catalysis had to be supervised by his various assistants. In 1900 he requested that he be relieved of his extensive, and increasingly oppressive, teaching duties. This was denied, so in 1906 he finally took early retirement at age 53.

After leaving his position at Leipzig, Ostwald's active involvement in chemical research ended, but in keeping with his belief in what he called "mental crop rotation," it was soon replaced by a variety of other interests extending over the remaining 25 years of his life, including history of chemistry; philosophy of science;

the quantification of color theory; active involvement in the Monist movement; an interest in streamlining the organization and transmission of scientific knowledge by adopting a simplification of Esperanto, known as Ido, as an auxiliary language for use in scientific publications; and the design and construction of a large home known as Haus Energie in Grossbathen, which has been preserved as a museum. Indeed, one historian has estimated that during his lifetime Ostwald wrote nearly 50 books, 500 papers, and over 5000 book reviews, making it impossible to adequately summarize his life and work in a mere book review.

In general Jack's translation is excellent, though on occasion it betrays an underlying German sentence structure and a more liberal translation would have served the reader better, not to mention a more liberal

use of commas. Scholz has supplemented Jack's translation with numerous clarifying footnotes with respect to both the more obscure names and the various books and papers mentioned by Ostwald, and has also provided a descriptive name index. In the original German volumes Ostwald included very few photographs. Though these are reproduced in the translation, my only disappointment is that the editors did not take this opportunity to enrich their work with the many photos of Ostwald and his activities that have long been available in the chemical literature and on the internet. But this is nit picking and nothing but accolades are due to both Jack and Scholz for this wonderful contribution to the history of chemistry.

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Pioneers of Magnetic Resonance, E. Thomas Strom and Vera V. Mainz, Eds., American Chemical Society, Washington, DC, ACS Symposium Series 1349, Distributed in Print by Oxford University Press, 2021, xi + 236 pp, ISBN 9780841237100, \$175.

This volume, edited by E. Thomas Strom of the University of Texas at Arlington and Vera V. Mainz of the University of Illinois at Urbana-Champaign, presents a series of papers based on an American Chemical Society symposium from the Division of the History of Chemistry (HIST), held at the Spring 2019 National Meeting in Orlando, Florida. The symposium celebrated individuals who pioneered the sister fields of electron paramagnetic resonance (EPR) spectroscopy and nuclear magnetic resonance (NMR) spectroscopy. In the volume, five NMR chapters are followed by six EPR chapters. The volume in general is a pleasure to read—just sit back and enjoy hearing from authors, many of whom were pioneers in the fields themselves, reminisce and discourse about a subject that clearly is close to their hearts, as well as mine.

The structure of the book is nearly perfect. The volume is bookended by two technical (sometimes too much so) chapters on the initial discovery of NMR and

on the early history of EPR with a focus on relaxation, respectively by Carmen J. Giunta and editor Mainz and by Sandra S. Eaton and Gareth R. Eaton. An unfortunate omission on the NMR side is the story of the MIT development of high resolution spectra of solids, which was included in the symposium with a talk by Robert Griffith that did not generate a chapter. Similarly, a presentation by Morton Meyers and editor Strom on the development of magnetic resonance imaging (MRI) was not brought to print because of unspecified copyright issues. These topics would have rounded out the subjects nicely. Often a multi-author symposium volume is uneven in terms of style, structure, and content, but in general this volume is excellently constructed and edited. Some of the authors, however, spent too much time on their own work or deviated from the focus of the pioneers, for example, by bringing their subject too much into the modern era. John Waugh and John D. Roberts were the only NMR pioneers and Clyde Hutchison the only EPR pioneer not given proper attention in my estimation, but other readers may have other favorites. The editors in the Preface steer the reader to more comprehensive histories of these fields to fill in the gaps.

Chapter 1 gives a well balanced presentation of the discovery of the NMR phenomenon by Rabi, Purcell,

and Bloch, who respectively received the 1944 and 1952 Nobel Prizes. A common and welcome thread that is established in this chapter and maintained throughout the volume is a description of the background and personal life of the individuals. Herbert Gutowsky is the subject of the second chapter, by his student H. N. Cheng and his colleague Gregory S. Girolami. The chapter also establishes an unexpressed theme of how much NMR had roots in what Nobelist H. C. Brown of Purdue liked to call America's Heartland—the Midwest and Great Plains. Not only was Gutowsky's entire career at the University of Illinois, but he grew up on a dairy farm in Michigan. Purcell came from Illinois and went to college at Purdue. Donald Woessner, the subject of Chapter 4, also grew up in Illinois, went to Carthage College in Wisconsin, and attended graduate school at the University of Illinois. Edward Stejskal, the subject of Chapter 5, was born in Chicago and received both his bachelor and doctoral degrees at the University of Illinois. Jacob Schaefer, the author of Chapter 5 and co-worker of Stejskal at Monsanto in St. Louis, went to high school in Ohio and received his Ph.D. from the University of Minnesota.

When Gutowsky began his academic career, NMR was still the esoteric domain of physicists, although Proctor and Yu had discovered "The Dependence of a Nuclear Magnetic Resonance Frequency upon Chemical Compound" (the title of their 1950 paper in *Physical Review*). These authors coined the awkward term "chemical shift" to highlight its alien identity from the realm of physics. It was Gutowsky who illustrated the value of the chemical shift in the period 1950 to 1952 with fluorine compounds in particular and later with hydrogen atoms in organic compounds. Moreover, with his student David W. McCall and his physics colleague Charles Schlichter at Illinois from 1951 to 1953, he discovered and explicated the indirect spin-spin coupling constant J . Particularly with C. H. Holm, Gutowsky in 1956 described the importance of NMR spectroscopy for studying rate processes at equilibrium through lineshape changes. Thus he completed a trifecta of discoveries that defined NMR as a structural and dynamic tool in organic and inorganic chemistry: chemical shift, coupling constant, and chemical exchange. John D. Roberts at MIT and Caltech contemporaneously was building the field of organic NMR applications. This pair would have been a perfect choice for the Nobel Prize in Chemistry.

Pierre Laszlo, a NMR pioneer himself, presents a personal view of a number of individuals with whom he interacted. More like vignettes, his biographical comments on Anatole Abragam, Pierre Grivet, John Waugh, Jeremy Musher, Martin Karplus, Frank Anet,

Paul Lauterbur (for his pre-MRI contributions), Ray Freeman, Sture Forsén, and M. Robert Willcott treat both recognized and unappreciated giants. In particular, I would like to underscore the contributions of Freeman of Varian, Oxford, and Cambridge, who gave us not only key pulse sequence but always made his work entertaining, both in presentation and in content (we are indebted to him for the immortal and essential pulse sequences INEPT and INADEQUATE).

The chapter on Donald Woessner is an unexpected but welcome component of this volume. Woessner made many, largely underappreciated, theoretical contributions to NMR spectroscopy, which are described beautifully by his former colleague, editor Strom. The chapter brings attention to Woessner's experimental contributions, particularly with zeolites and concerning water in living cells. This chapter also contains a section on the controversy concerning the omission of Raymond Damadian from the 2003 Nobel Prize for the discovery of MRI. Although I disagree with the conclusions concerning the importance of Damadian's work, this chapter makes public important correspondence between Woessner and Damadian, which was provided to Strom by Woessner's son, Dr. Richard Woessner.

The last NMR chapter is about the contributions of Edward Stejskal to hardware for obtaining high resolution spectra of solids through removal of dipolar broadening and chemical shielding anisotropy with cross polarization and magic angle spinning. The author, Jacob Schaefer, was an integral part of these contributions and sadly passed away in 2022, following the publication of this volume. This chapter does not substitute for the omitted chapter from the talk by Griffith concerning the similar work by John Waugh at MIT, but it does highlight the absolutely critical contributions made at the Monsanto Company to this field. All workers in the field of solid-state NMR spectroscopy are in debt to this group and the subsequent academic work of the two principals respectively at North Carolina State University and Washington University.

My expertise is not in EPR spectroscopy, so I cannot review the six chapters on this field in any technical fashion. Nonetheless, I admit to being spellbound by the presentation by David E. Lewis of the University of Wisconsin-Eau Claire on the discovery of the phenomenon by Yevgenii Konstantinovich Zavoiskii. Although Zavoiskii ultimately received appropriate recognition in his country, the then Soviet Union, the difficulties he experienced as professor at the Kazan Federal University in the Volga region of Russia, far from the elite

axis from Moscow to St. Petersburg, are worthy of a soap opera. He wrote two distinct doctoral dissertations on different subjects, as for some reason his first one never was submitted. He was accused of spreading fascist propaganda in the late 1930s during the critical period of Stalin's Great Purge, when many reputable scientists were the targets of show trials that resulted in numerous executions. Supposedly, Zavoiskii had showed crystals in a course in physics that appeared to exhibit a swastika pattern, but the commission investigating the allegations did not corroborate them and the case was dropped. When Zavoiskii reported the initial EPR signals of manganese(II) sulfate in 1944 in his second dissertation, the examiner rejected the work on the basis that a single physicist working in the boondocks could not have accomplished the claims. His unlikely savior was the future Nobelist Pyotr Leonidovich Kapitsa, who not only believed the results but offered Zavoiskii the opportunity to reconstruct the instrumentation and replicate the results at the acceptable venue of the Institute of Physics of the USSR Academy of Sciences in Moscow. He succeeded in just a few weeks, and the results were published the same year in English in the *Journal of Physics* but still overlooked. The obscurity of the journal and the timing during the last years of World War II led to lack of recognition in the West until the phenomenon was rediscovered by Brebis Bleaney at the University of Oxford and others after the war. The author Lewis clearly required fluency in the Russian language to complete his coverage of Zavoiskii's life and travaux.

The next four chapters profile individual EPR pioneers. James R. Norris explores the life and work of Samuel Weissman, who received his Ph.D. from the University of Chicago and carried out his work at the Washington University (St. Louis), where in 1952 with George Pake and Jonathan Townsend he reported the seminal discovery of hyperfine splitting in EPR spectra. Jack Freed describes the work of George K. Fraenkel at Columbia University, who constructed his own groundbreaking spectrometers and studied a variety of paramagnetic aromatic molecules such as bianthrone and semiquinone derivatives. Only this chapter prefers and uses the alternative term electron spin resonance (ESR) over EPR. Alex I. Smirnov presents the work of R. Linn Belford, who was an undergraduate at the University of Illinois and returned there for his academic career. He

studied mainly paramagnetic metal ion complexes but also helped establish the Illinois EPR Research Center, where construction of novel EPR instrumentation was emphasized. Lawrence J. Berliner outlines the career of Harden M. McConnell, who worked at Shell Development Company, the California Institute of Technology, and Stanford University. Only McConnell can be credited with making fundamental discoveries in both the NMR and the EPR fields. He developed the famous McConnell equation at Shell, relating the observed EPR hyperfine splitting constant A to the spin density ρ at carbon as in the benzene radical anion ($A = Q\rho$). Also at Shell, McConnell described the dependence of shielding at a nucleus on the diamagnetic effects of bonds elsewhere in a molecule, explicating the NMR chemical shifts of aromatics, double bonds, triple bonds, and other anisotropic organic structural elements. He developed the spin labeling technique that proved instrumental in moving EPR spectroscopy into biological systems. Berliner does an admirable job in describing McConnell's eccentricities, which I experienced in a first-year course in quantum mechanics at Caltech in 1963. At the end of the course he announced that, for the final examination, we were to make up our own problem and solve it. At first glance, the assignment seemed to be a simple way for the instructor to avoid writing a final, but never did we struggle so hard with a final. We quickly learned the eternal lesson of instructors and research advisers everywhere. It is straightforward to identify simple (unimportant) problems with easy solutions and difficult (important) problems with no solution, but it is no trivial exercise to find a challenging but solvable problem. We all learned that lesson from McConnell.

McConnell, with his contributions to both NMR and EPR fields, is an appropriate icon to illustrate their interconnectivity. The dominance of pioneers profiled in this volume from America's Heartland extends to EPR spectroscopy (Weissman, Belford). The unprofiled Clyde A. Hutchinson Jr. was born in Ohio, graduated from Cedarville University, received his Ph.D. from Ohio State University, and had his career at the University of Chicago. Particularly notable is the role that the University of Illinois at Urbana-Champaign played in both fields.

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Science: Has its Present Past a Future? Selected Essays by Arnold Thackray, Jeffrey L. Sturchio and Bruce V. Lewenstein, Eds., Seavoss Associates Publishing, Ithaca, NY, 2022, 667 pp, ISBN 979-8551167730, \$24.95.

The career of Arnold Thackray is truly *sui generis*; as a young, bold academician, a pioneer in establishing a field of scholarship, founding an academic department, editor of respected scholarly journals, an entrepreneur who helped create an institute housed in brick and mortar. In 1982, the University of Pennsylvania, in partnership with the American Chemical Society, formed the Center for the History of Chemistry (CHOC), with Professor Thackray as its president, joined in 1984 by the American Institute of Chemical Engineers. One can only try to imagine the bureaucratic and political obstacles overcome. In 1992, Thackray helped launch and lead its successor, the Chemical Heritage Foundation (CHF), its headquarters and museum in a large, handsome modernized building in Old City, Philadelphia, occupied in 1994, well-staffed and underwritten with a huge endowment. Subsequently, Thackray initiated the Life Sciences Foundation and in 2015, this organization was united with the CHF to form the Science History Institute (SHI). The national and international impacts of Thackray's varied contributions cannot be overstated or even readily classified. The three co-authors of the *Preface* pose the key question about Thackray: "Hedgehog" or "Fox," quoting Isaiah Berlin: "The fox knows many things, but the hedgehog knows one big thing." The authors conclude that, despite Thackray's incredibly wide ("fox-like") range of activities, he "has been true to an 'unchanging, all-embracing vision' of the significance of chemistry and its heritage—and he has won the world to embracing it with him." Hence, "by nature...quite a hedgehog."

This book is, for the most part, a *sammelband* of selected writings by Dr. Thackray, celebrating his 80th birthday and the 50th anniversary of the University of Pennsylvania's History & Sociology of Science (HSS) Department. Roughly, ten percent is *festschrift*, the largest part being recollections by ten of his nineteen former students. These provide insight into the character of the young and early-middle-aged powerhouse scholar/administrator and are themselves "worth the price of admission." Any person who today doubts the "utility" of a degree in the humanities should read the profiles of Thackray's students. Sturchio, briefly my faculty colleague at New Jersey Institute of Technology and long-time friend, moved from academe to become a corporate archivist at Merck and thence to other high-level indus-

trial and foundation leadership positions, sharing many of his mentor's skillsets. His co-editor, Lewenstein, while enjoying an academic career at Cornell, was a founding member of the university's Science, Technology & Society (STS) program, which he chaired for seven years, and helped build the academic field of public communication of science and technology (PCST).

Following the Preface and Thackray's Introduction, Part I, "Young Discipline, Young Man," begins with his review of Volume IV of Partington's *A History of Chemistry* combined with Ihde's *The Development of Modern Chemistry*. This "brash review" (see the above-noted Preface) is an uncompromising, albeit mostly respectful, examination of the two highly respected mid-twentieth century works. Particularly hard on Partington, a major theme of Thackray's is the near absence of historical and sociological perspective. Perhaps the 2022 six-volume series *A Cultural History of Chemistry*, co-edited by Peter J. T. Morris and Alan Rocke, will finally satisfy Thackray's exacting standards. Young Thackray published extensively on Isaac Newton as well as the development of atomic theory and John Dalton, and his careful reading of correspondence helps clarify the evolution of atomic theory typically presented in introductory chemistry textbooks as appearing fully formed in 1803 or 1805 or 1808.

Part II, "Scouting New Directions," begins with the eponymous "Science: Has Its Present Past a Future?" This ironic title focuses readers on another Thackray theme: the neglect of contemporary science by historians of science, lessons offered to them and gained from the past. This section is challenging reading for a non-historian such as myself. A new term for this reviewer, but known to historians: "prosopography" as a research tool is the subject of the third essay. As Casey Stengel would say: "You could look it up."

Thackray left Cambridge to arrive at the younger Cambridge in 1967 as Visiting Lecturer at Harvard, thence in 1968 as Assistant Professor, University of Pennsylvania, beginning his climb to Joseph Priestley Professor of History and Sociology of Science and retiring as Emeritus in 1996. The first essay (1971) in Part III, "Discovering America," has the provocative title "Reflections on the Decline of Science in America and on Some of its Causes" and compares the evolution of science societies in England and subsequently in the United States. He advocates that these societies must evolve in response to the enormous societal and political disruptions of the period. Only at the end does Thackray show his hand: "Such evolution would forestall any need for the serious use of the title I chose, more for its historic

associations than its present accuracy.” Other essays in this section examine university-industrial interactions, entrepreneurship, and public policy.

Part IV, “Dissecting the Discipline,” focuses on the historiography of science. Much as in Part II, this is an area largely unfamiliar to this reviewer. However, both Parts II and IV are helpful in that they provide a “taste” of how historians work, the introduction of statistics and other metrics, and the challenges the field faces. Part V, “Editorials,” were published as Editor of *Isis* (1978-85), a quarterly founded in 1912, and Editor of *Osiris* (1985-94), the journal for annual thematic issues, started by George Sarton in 1936, published through 1968 and “revived” by Thackray. Part VI, “Arnold Thackray’s

Ph.D. Students,” consists of brief biographical sketches further demonstrating Professor Thackray’s decades-long impact. Part VII, “Reflections by Former Students,” as hinted at earlier, makes for delightful reading. Part VIII, “Arnold Thackray’s Biography and Curriculum Vitae,” is the short form outlining an amazing career.

This book will be a fine addition to institutional libraries, especially those that have STS programs or variants thereof. Chemists, like the present reviewer, who lacks true expertise in history will find interest in obtaining some exposure to the techniques employed by and challenges faced in applying historiographical methods.

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2022 Franklin-Lavoisier Prize

The Science History Institute and the Paris-based Fondation de la Maison de la Chimie have announced Joseph Gal as the winner of the 2022 Franklin-Lavoisier Prize. The organic chemist and University of Colorado School of Medicine professor emeritus was recognized for his extensive research on the life and work of French chemist and microbiologist Louis Pasteur. This prestigious award recognizes efforts in the preservation or promotion of the entwined scientific heritage of France and the United States. In conjunction with the award, a recorded lecture by Gal titled “Louis Pasteur’s Discovery of Molecular Chirality” is available online at <https://www.youtube.com/watch?v=qAmdS0dXzlg>.



2022 Citation for Chemical Breakthrough Awards

Five papers were selected for the ACS Division of the History of Chemistry's 2022 Citation for Chemical Breakthrough (CCB) awards. The awards were first given in 2006, and they have been administered throughout that period by Jeffrey I. Seeman. The papers recognized this year span over a century of chemical research from structural organic chemistry to DNA synthesis and conducting polymers. The awards in chronological order go to:

- Ghent University for August Kekulé's paper on the structure of benzene: A. Kekulé, "Sur la constitution des substances aromatiques," *Bulletin de la Société chimique (Paris)*, **1865**, 3, 98-110.
- Faculty of Medicine at the Université Paris-Cité for Joseph-Achille Le Bel's paper on tetrahedral carbon: J.-A. Le Bel, "Sur les relations qui existent entre les formules atomiques des corps organiques et le pouvoir rotatoire de leurs dissolutions," *Bulletin de la Société chimique (Paris)*, **1874**, 22, 337-347. Le Bel was affiliated with the Paris École de médecine at the time. (The award recognized J. H. van't Hoff's 1874 publication on tetrahedral carbon in 2012.)
- University of California, Berkeley, for a paper that proposes hydrogen bonding to explain association in liquids: Wendell M. Latimer and Worth H. Rodebush, "Polarity and Ionization from the Standpoint of the Lewis Theory of Valence," *J. Am. Chem. Soc.*, **1920**, 42, 1419-1433.
- Northwestern University for a paper on synthesis of DNA fragments on solid supports: Robert L. Letsinger and V. Mahadevan, "Stepwise Synthesis of Oligodeoxyribonucleotides on an Insoluble Polymer Support," *J. Am. Chem. Soc.*, **1966**, 88, 5319-5324.
- The University of Pennsylvania for synthesis of conducting polymers: Hideki Shirakawa, Edwin J. Louis, Alan G. MacDiarmid, Chwan K. Chiang, and Alan J. Heeger, "Synthesis of Electrically Conducting Organic Polymers: Halogen Derivatives of Polyacetylene (CH)_x," *J. Chem. Soc., Chemical Communications*, **1977**, 578-580.

Nominations for the 2023 Citation for Chemical Breakthrough awards are open through March 1, 2023. The nomination form and much more information on CCB awards are available at http://acshist.scs.illinois.edu/awards/citations_chem-breakthroughs.php

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The Back Story

Jeffrey I. Seeman, University of Richmond, Richmond, VA, jseeman@richmond.edu

Vladimir Prelog, Albert Eschenmoser and I. A Friend of a Friend is a Friend

As the editor of his autobiography, I got to know Vlado Prelog (1906-1998) reasonably well. Prelog was famous for his anecdotes, quite humorous but always with a pedagogical slant. Additionally, his anecdotes were often “insider jokes,” understandable only to members of an ingroup—us scientists. I would call Prelog regularly yet infrequently, always with my pencil and paper in hand to record his wisdom.

In 1989, I attended the 25th Euchem Conference on Stereochemistry—the famous Bürgenstock Conference—and quite happily was invited by Prelog to ride back to Zürich with him and Albert (b. 1925) and Elizabeth Eschenmoser (Figure 1). Along the way, Prelog told a story about his mentor and former ETH Professor Leopold Ružička (1887-1976) and the Pope. I recall the moment quite clearly. I suggested to Prelog that he include that anecdote in his autobiography. Prelog’s happy expression turned long-faced and solemn. Mrs. Eschenmoser explained, “Dr. Seeman,” she said, “you are a dangerous man.” In self-defense, I ask you: What else is a researcher but an ever-foraging optimist?

In the summer of 1997, I was able to visit Zürich and share with Prelog, Eschenmoser, Duilio Arigoni and Jack



Figure 1. Elizabeth Eschenmoser, Vladimir Prelog, Albert Eschenmoser; Zürich, May 7, 1989. Photograph courtesy J. I. Seeman.

Dunitz—the so-called ETH mafia—the documentary video I had produced on Derek Barton, Carl Djerassi and Koji Nakanishi for my presentation at that year’s National Organic Symposium. Prelog, who died just a few months later, could not join the Eschenmosers and me for dinner that night (Figure 2). It was through Prelog that I had become friends of the Eschenmosers. Friends of a friend are friends. I call Eschenmoser regularly yet infrequently, always with my pencil and paper in hand to record his wisdom.



Figure 2. Elizabeth and Albert Eschenmoser; Zürich, 1997. Photograph courtesy J. I. Seeman.

Quite recently, almost 32 years later, I shared a wonderful anecdote of Prelog’s with Eschenmoser. This was a moment of multiple “ins” for Albert and me. We were also sharing our deep affection for our friend Prelog. Memories must serve us. I did not need to refer to my notes to tell the story.

“No one knows who was the second Fellow of the Royal Society,” Prelog had told me on the phone so many decades ago. I was curious. “How could that be?” I asked Prelog. “When I went there for my induction,” Prelog related, “when I was signing the ceremonial book of Fellows, I asked to see Newton’s signature. They opened the book to the first page, and with my finger outstretched, I was about to point to Newton’s signature, as so many had done before me. There was Newton’s signature, but underneath that, obliterated by numerous ‘finger touches’ was a blotched line!” Essentially an empty space between the first and third signatures.”

Albert and I laughed heartedly at this joke! He certainly had heard that story before, from Prelog himself.

The night before this call, I had exchanged several emails with Masahiro Murakami who had just published a wonderful biographical memoir on the famed synthetic organic chemist Teruaki Mukaiyama. Mukaiyama had played a major role in my life, introducing me to Tetsuo Nozoe; that's another story. In Murakami's article was a wonderful photograph of Mukaiyama and Eschenmoser, which Murakami kindly forwarded to me, and I had forwarded it to Albert (Figure 3). Eschenmoser and Mukaiyama's happy moment resonates clearly with all of us. We feel the levity of their moment.

Friends of friends are friends. As a community and as individuals, we share the joys of chemistry and the joys of life. We are indeed blessed.

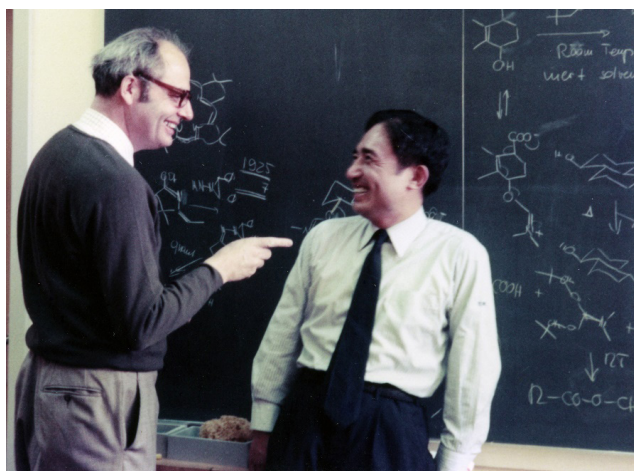


Figure 3. Albert Eschenmoser and Teruaki Mukaiyama, Tokyo, ca. 1990s. Photograph courtesy M. Murakami.

Fire Destroys Liebig's Historic Lecture Hall

On the evening of December 5, 2022, a fire broke out in the historic lecture hall of Justus Liebig's laboratory in Giessen, Germany. Due to the fire damage, the Liebig museum will remain closed until further notice.

A fire destroyed parts of the Liebig Laboratory's historic auditorium at around 9:30 pm. Parts of the analytical laboratory, the pharmaceutical laboratory and the library were affected. While the other rooms were mainly damaged by the developing soot, the lecture hall was directly affected by the fire. The front area together with the bench for experiments were damaged directly by the flames.

A popular lecture-demonstration for families had taken place in the historic lecture hall earlier on the day of the fire. The tenant who lives in the building quickly alerted the fire brigade, thereby preventing further spread of the fire and additional damage. According to police spokesman Jörg Reinemer, there are no indications of intentional arson. Police estimate the damage at 100,000 euros.

As a consequence, the museum is especially dependent on donations and asks for support. For further information see: <https://www.liebig-museum.de/>.

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